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Innovative Housing Grants Program

DEVELOPMENT OF A PVC FOLDING DOOR USING ALBERTA TECHNOLOGY AND MATERIAL

November 1989

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FOREWORD

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EXECUTIVE SUMMARY

This project undertook the design, development and testing of an "accordion" style folding door for closets and utility areas in both single family and multiple occupancy dwellings. The end product is manufactured from Alberta-produced polyvinyl chloride (PVC) materials, utilizing plastic extrusion techniques.

A market analysis indicated that the Alberta market for this style of door is presently supplied by wood or woven materials from the Far East, plastics from France or Taiwan, and metal panels from Eastern Canada. The primary purpose of this project was to develop a door of superior quality at a competitive price, thereby allowing Alberta industry the opportunity to compete for the Alberta market, which is conservatively estimated at $850,000 per year.

Major steps in the development of the product included detailed design of each component, design and fabrication of the extrusion dies, prototype production, performance testing, and certification testing. Design work focused on simplicity, ease of installation, and adaptability to non-ideal installation conditions. Subsequent performance testing of prototypes demonstrated that these design criteria had been well-achieved. More specifically, the project reached the following conclusions:

1. The door has passed the flame-spread testing necesary for recognition within the scope of the Alberta and National Building Codes.

2. Rigorous operational testing has demonstrated the PVC door's durability, reliability, and adaptability.

3. On basis of cost estimates the PVC folding door can be produced and sold at a lesser price than that offered by the major (provincially) imported competitors.

4. The raw materials necessary to meet market requirements currently exist in abundance in Alberta.

5. Manufacturing expertise is presently available in Alberta.

Commercialization efforts will encounter some obstacles that must be overcome. Considerable capital expense will be incurred through initial manufacturing-related costs, establishment of the necessary sales and distribution networks, and production and distribution of advertising designed to reach the target market. Additionally, there will be a certain "take-up" time during which the product will have to prove itself in the commercial arena by demonstrating its attributes against competing, established products. This would involve initially slow production rates by a facility geared towards large scale production for the purpose of achieving economies of scale.

DEVELOPMENT OF A PVC FOLDING DOOR USING ALBERTA TECHNOLOGY AND MATERIAL

1.0 INTRODUCTION

1.1 Purpose

Folding ("accordion" style) doors occupy a significant market niche in the residential building industry. They are typically used as closet and utility area closures in single family and multiple-occupancy dwellings. Currently there are no Alberta-based manufacturers of folding doors for residential applications. At best, the components for folding doors are imported into the Province for assembly and subsequent sale. The Alberta industry is presently supplied by plastics from France or Taiwan, metal panels from Eastern Canada, and, to a lesser extent, by wood or woven materials from the Far East.

This project encompassed the development of a higher quality, less expensive folding door than is currently available to the Alberta market. Development focused on the use of Alberta-produced polyvinyl chloride (PVC) materials, with a process conducive to manufacture by Alberta industry.

1.2 Scope

The work comprised the advancement of the product from the preliminary design stage to the production-ready stage. This included:

1. a literature search to determine the present state of the industry;

2. a patent search to determine the patentability of the product;

3. an investigation into the certification and testing requirements for PVC folding doors;

4. a market analysis to determine the demand and the current industry pricing;

5. consideration of the PVC extrusion process and its effect on design, cost, and performance;

6. development of a working design of the folding door which included the design of extrusion dies for several of the PVC components;

7. construction, testing and fine-tuning of the dies;

8. production and evaluation of prototypes in terms of performance and cost; and

9. certification testing.

1.3 Methodology, Approach and Organization of Material

This report outlines the steps taken to fulfill the objectives of the project. Sections 2, 3, and 4 describe the literature survey undertaken, the patent search process, and the requirements for approval and certification of the folding door in Alberta. Section 5 presents a market analysis, from which viability and pricing criteria are determined. Section 6 discusses the rationale for selecting PVC as the raw material and extrusion as the manufacturing process. Development of the detailed design and subsequent costing of the folding door is described in Section 7. Production, in-house testing and evaluation of prototype doors is reviewed in Section 8. Section 9 presents the results of certification testing as

carried out by an accredited Canadian laboratory. Section 10 contains discussion on the conclusions drawn from the work, d a brief description of plans to introduce the Alberta folding door to the marketplace.

1.4 Research Methods

Background research sources included existing literature reviews and input from various Government agencies including Canada Mortgage and Housing Corporation (CMHC), the Canadian Standards Association (CSA), Alberta Labour, Building Standards Branch, and the Alberta Research Council.

Design- and production-related research included interviews with experts in the fields of PVC extrusion, die making, and the manufacture and distribution of folding doors. Additionally, users of folding doors (including builders, architects, consumers, Alberta Mortgage and Housing Corporation and other agencies) were consulted to determine their needs.

2.0 LITERATURE REVIEW

It was found that very little printed information dealing with the design, application, and manufacture of folding doors exists. The literature review was therefore necessarily limited to existing promotional materials such as trade brochures and specification sheets. In essence, the review of existing literature did not contribute useful data for subsequent design and manufacturing work. It did, however, reinforce the basic premise of the project - there is indeed room in the marketplace for a well-manufactured, competitively priced, Alberta-produced folding door. Further discussion in this regard can be found in Section 5 of this report.

3.0 PATENTS SEARCH

In order to establish the originality of the design and to confirm its eligibility for patenting, a computer search of the "World Patents Index" was conducted by the Alberta Research Council in Edmonton. It showed no similar products patented in Canada or elsewhere.

4.0 DETERMINATION OF CERTIFICATION AND PRODUCT APPROVAL REQUIREMENTS

4.1 Certification Requirements

The appropriate standards and certification organizations were consulted regarding standards governing the use of folding doors in residential construction in Canada. The Canadian Standards Association indicated that folding doors do not require their certification. Representatives of CMHC advised that, since folding closet doors are not referred to specifically in the National Building Code, standards for them are the same as those that may be specified by the Provincial code jurisdictional authorities. Alberta Labour, Building Standards Branch advised that the Alberta Building Code (ABC) does not specify that a folding door must be made of a specific type of material, but referred to the following clauses of the code:

> 3.1.11.1.(1) Interior finish material shall include any material that forms part of the interior surface of a floor, wall, partition or ceiling such as
> (a) interior cladding of plaster, wood or tile,
> (b) surfacing of fabric, paint, veneer or wallpaper,
> (c) doors, windows and trim,
> (d) lighting elements such as light diffusers and lenses forming part of the finished surface of the ceiling, and
> (e) carpet material that overlies a floor, when such floor is not intended as the finished floor.

3.1.11.7.(1) In buildings required to be of noncumbustible construction,

(a) the flame-spread ratings in Article 3.1.4.5 shall apply in addition to the requirements in this Subsection, and

(b) the flame-spread ratings for exits in this Subsection shall also apply to any surface in the exit that would be exposed by cutting through the material in any direction, except that this requirement does not apply to doors, heavy timber construction in sprinklered buildings and fire-retardant treated wood.

3.1.4.5.(3) Combustible millwork, interior cladding and finishing materials shall be limited to

(g) interior wall finishes other than foamed plastics that

(i) are not more than 25 mm in thickness, and

(ii) have a flame-spread rating of not more than 150 on any exposed surface, or any surface that would be exposed by cutting through the material in any direction.

(h) interior ceiling finishes other than foamed plastics that

(i) are not more than 25 mm in thickness, except for exposed fire-retardant treated wood battens, and

(ii) consist of a material having a flame-spread rating of not more than 25 on any exposed surface or on any surface that would be exposed by cutting through the material in any direction or fire-retardant treated wood except that not more than 10 per cent of the ceiling area within each fire compartment is permitted to have a flame-spread rating of not more than 150.

The underlined text in the preceding excerpts represents the code criteria deemed applicable to the PVC folding door.

Requirements for certification for the folding door were therefore determined as and limited to flame-spread restrictions. Specifically, the flame-spread rating must be less than 150. The method for determining flame-spread rating is defined by Underwriters Laboratories Canada publication CAN4.S102.2-"Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials and Assemblies".

5.0 MARKET ANALYSIS

5.1 Market Study

In residential applications there are presently two major types of folding doors in use in Alberta. These are PVC doors manufactured in Europe or the Far East, and a door from Eastern Canada comprised of metal panels with PVC hinges. This does not imply that there are no other types of doors available in the Alberta marketplace, but the other types do not have a significant impact on the market.

There is no data available that specifically identifies the demand for folding doors in the marketplace, but a variety of sources were used to estimate the possible market for the product in Alberta and the rest of Western Canada. Potential applications for folding doors include the following market groups:

1. New ownership housing, both single detached and multiple, built by the private sector;
2. New rental housing;
3. Existing rental housing;
4. Government subsidized housing;
5. Renovation market; and
6. Commercial construction (utility and service vestibules).

CMHC estimates predict a total of 12,500 (9,900 single family, 2,600 other) dwelling starts in Alberta for 1989. Additionally, CMHC reports that there were 190,946 rental units in Alberta as of 1988. Both these figures indicate the substantial size of the potential market for folding doors for the purpose of initially outfitting new construction and for upgrading existing rental dwellings.

Another area of investigation was a study of the volume of sales of pre-assembled and packaged doors through lumber yards and hardware stores. It was estimated by sources closely related to this field that over $500,000 in annual sales are generated in Western Canada at the wholesale level. Of that total, approximately $175,000 in annual sales are generated in Alberta alone. Additionally, the annual Alberta wholesale market for sales to builders, contractors and renovators, is estimated by those involved in the fabrication industry as $350,000. Therefore, the total market for wholesale sales to Alberta lumber yards, hardware stores, builders, contractors and renovators is estimated as $525,000 annually. This market is presently supplied by products imported into Alberta.

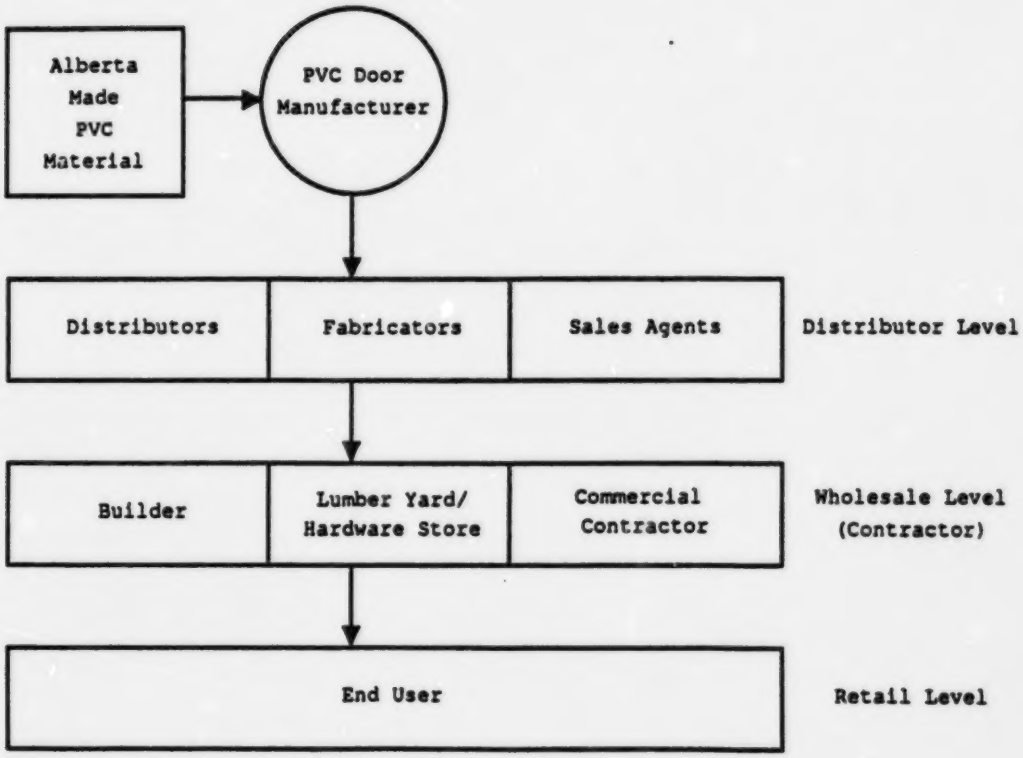
The first year of sales and production efforts for the PVC door would concentrate on gaining access to a significant portion of the Alberta market. Subsequent years' efforts would include an emphasis on penetration into the remaining western Canadian market along with continued efforts in Alberta.

Figure 5.1 indicates a possible network structure for a new folding door distribution system in Western Canada.

FIGURE 5.1 SALES AND DISTRIBUTION NETWORK

FIGURE 5.1 SALES AND DISTRIBUTION NETWORKS

Potential Western Canadian
Distribution Network



5.2 Current Industry Average Pricing

It was necessary to determine the current market pricing for existing products in order to determine the financial viability of an Alberta-produced product. Table 5.1 indicates the wholesale condensed and the contractor prices for metal panel and vinyl panel doors currently on the market. The wholesale condensed price refers to the cost of the unassembled materials to the Alberta distributor/fabricator. The contractor price refers to cost of the assembled door to the contractor/builder before retail mark-up. The difference in pricing between wholesale and contractor prices for the metal door is larger because more labour is involved in the assembly of the metal door once it has been received in Alberta.

TABLE 5.1 TYPICAL 4 FOOT FOLDING DOOR

	Wholesale Condensed	Contractor
Metal Panel	70.25	146.30
Existing Vinyl Panel	90.25	138.99

Therefore, in order for a new product to successfully compete in this market it is desirable that it should cost less than either of the two existing doors, and be of equal or better quality. These preferences directly influenced the manufacturing process, choice of materials and design of the proposed folding door.

6.0 SELECTION OF MATERIAL AND THE MANUFACTURING PROCESS

6.1 Polyvinyl Chloride (PVC)

Polyvinyl Chloride (PVC) was chosen as the manufacturing material for the proposed door for several reasons. The durability of PVC has been demonstrated through the extensive use of PVC products in the building industry. In particular, PVC windows and siding have consistently proven the weather and abuse resistant nature of this material. Additionally, PVC is readily available in Alberta, the manufacturing facilities currently exist in the province, and the price of Alberta PVC is low enough to achieve a price advantage.

6.2 The PVC Extrusion Process

PVC extrusion involves converting plastic pellets into a continuous uniform melt and forcing this melt through a die to yield a desired shape. The molten material must then be cooled back to its solid state as it is held in its desired shape so the end product can be realized. Examples of these end products (or "custom profiles" as they are also known) include items such as auto trim, house siding, window framing, pipes, and edge trim.

Figure 6.1 shows in detail the flow schematic of an extrusion assembly. (A similar set-up was utilized to produce prototypes of the PVC folding door.) The process begins when solid plastic pellets are poured into a hopper on the extrusion machine (see Figure 6.2). The pellets pass through a vertical opening in the feed section onto a rotating screw with spiral flights. The material is conveyed along the screw and heated inside the barrel. It must reach the die system in a totally molten state at an acceptable and homogeneous temperature such that it can be ejected through the die at a consistent output

rate to give shape to the profile. A variable speed puller near the end of the extrusion line pulls the molten material from the die through the various sizing, shaping and cooling stages to the cut-off saw which automatically cuts the profile to specified lengths to form a product that falls within given size tolerances.

Methods of shaping and cooling the melt to realize the end product are varied, depending on the shapes involved. Two methods would be required to shape and cool the components used in the manufacture of the proposed PVC folding door. The first process for cooling custom profiles without hollow sections is the simpler. It applies to components made from PVC materials that have high melt viscosities so they can be easily held in shape while cooling. These profiles can be cooled after leaving the extruder by forced air, immersion in water troughs, or by water spray methods.

The second and more difficult process is similar to that used in pipe extrusion. It is used to cool custom profiles with hollow sections. After leaving the extruder die the PVC is initially cooled through open water troughs and then pulled through vacuum sizing tanks. Here the melt is held for a short time in a vacuum chamber sizing sleeve. The outer diameter of the material hardens while it is held against the sizing sleeve by vacuum forces outside and air inside the extruded material. This process ensures that both the inside and the outside configurations of the custom profile are accurately realized.

FIGURE 6.1 FLOW SCHEMATIC OF A PROFILE EXTRUSION LINE

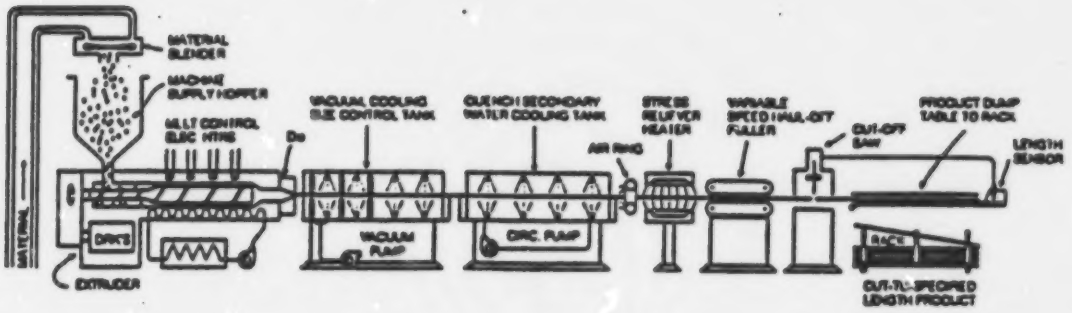


FIGURE 6.2 EXTRUSION MACHINE

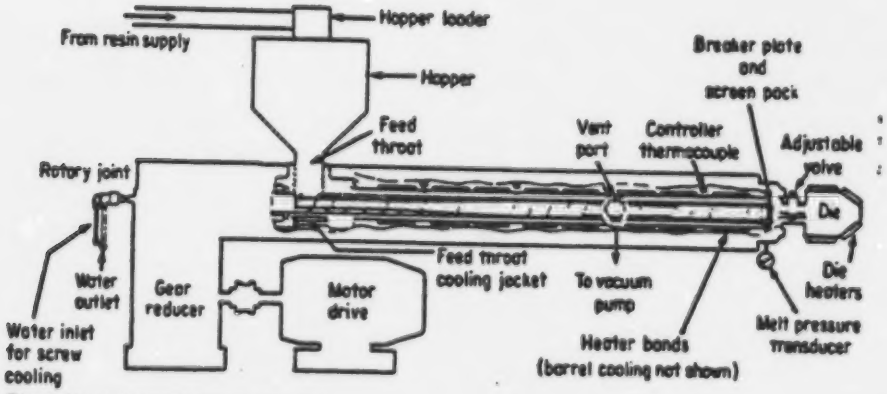


Fig. 1: Vented single screw extruder.

7.0 DESIGN

7.1 Design Considerations

The emphasis of the project was to design and manufacture an attractive, reliable, economical and easy-to-install door. Simplicity of style and the PVC extrusion manufacturing process facilitated the production of a quality product at a reasonable cost.

The PVC folding door was designed to consist of the fewest components possible. This resulted in cost savings and easy assembly. The door consists of ten different components. Figure 7.1 shows an overall front view and top view of an assembled door in an opening and illustrates how each component of the door relates to the others.

Six of these components can be manufactured in Alberta utilizing Alberta PVC. They are shown in cross-section in Figures 7.2 through 7.7. These include the full panels, the half panels, the flex hinges, the top track, the lead post, and the wall jamb. The remaining four components are specialty parts that are already available at reasonable cost. These include the handle, the magnet, the striker plate, and the trolleys. It proved more cost efficient to purchase these items than to manufacture them.

FIGURE 7.1 FRONT AND TOP VIEW OF PVC FOLDING DOOR

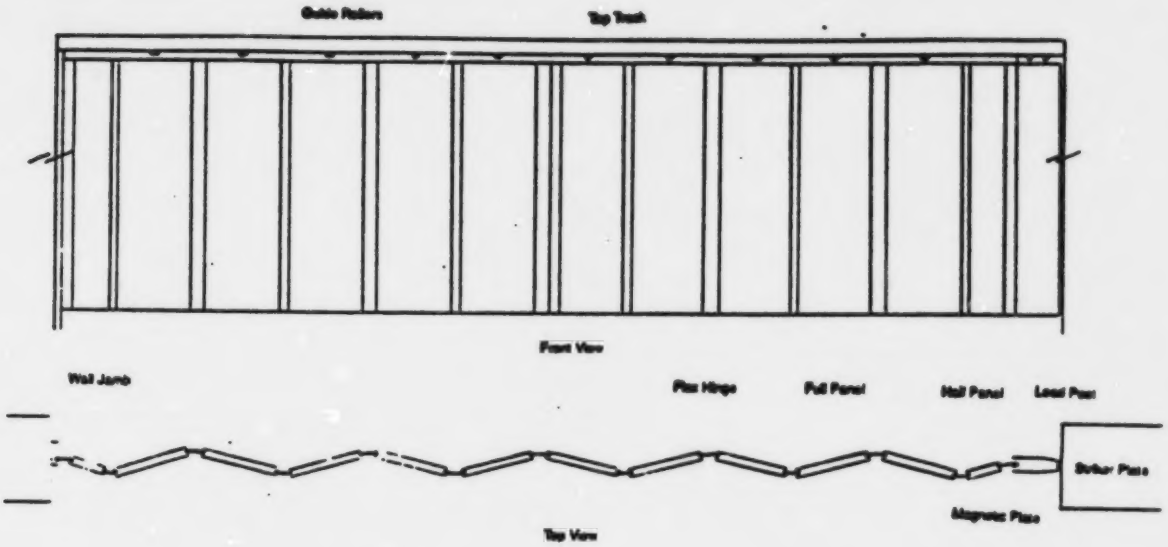


FIGURE 7.2 FULL PANEL

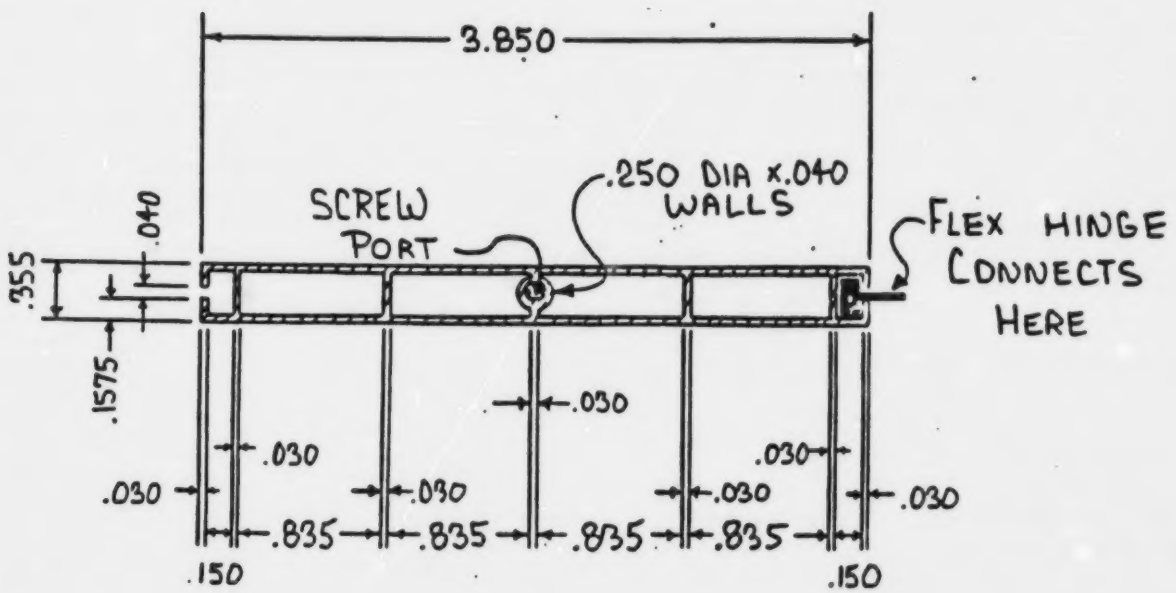


FIGURE 7.3 HALF PANEL

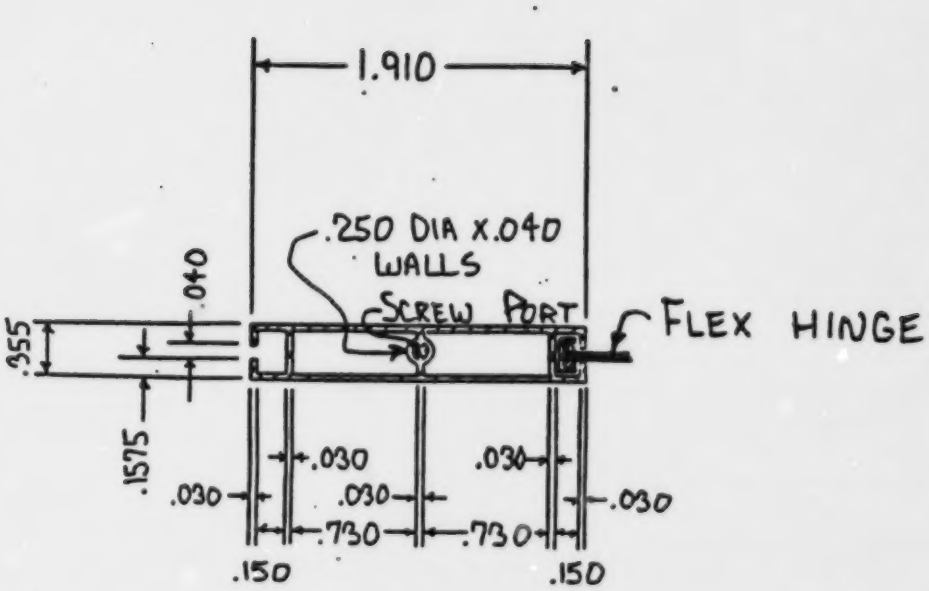


FIGURE 7.4 FLEX HINGE

(Note: The hinge is extruded from a softer grade of PVC than the panels, posts, and header, because it requires greater flexibility.)

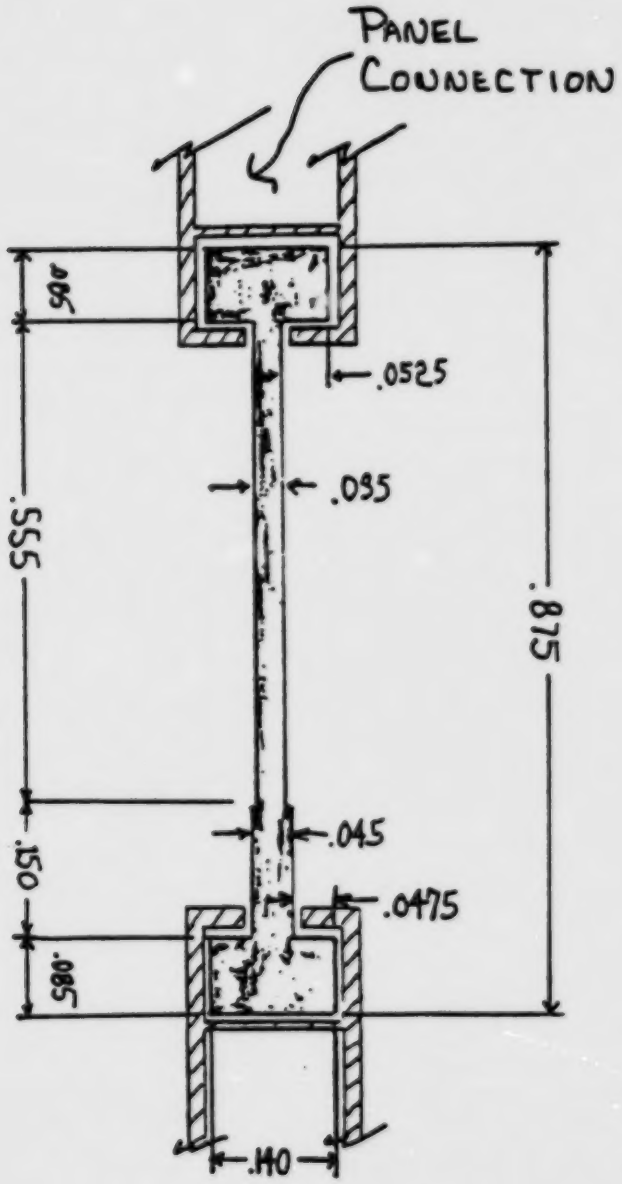


FIGURE 7.5 TOP TRACK

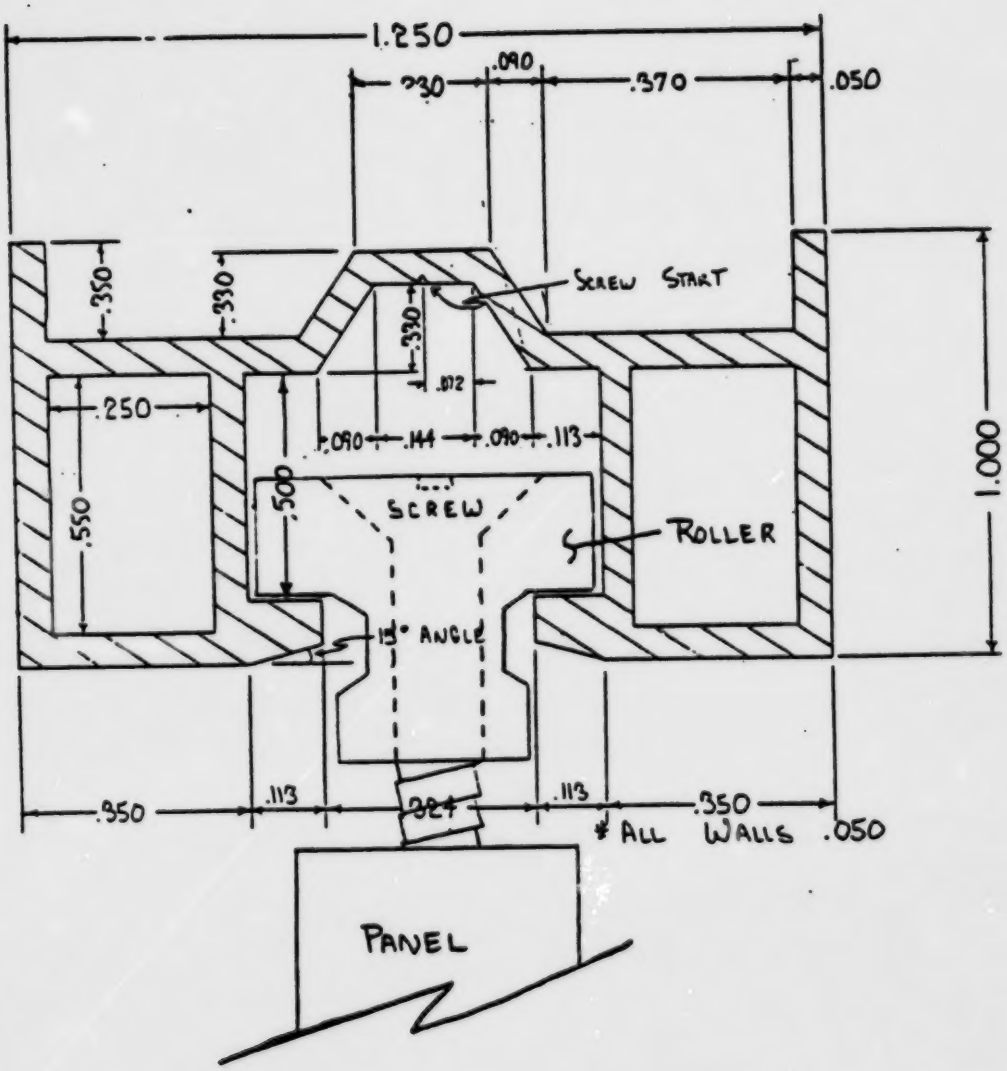


FIGURE 7.6 LEAD POST

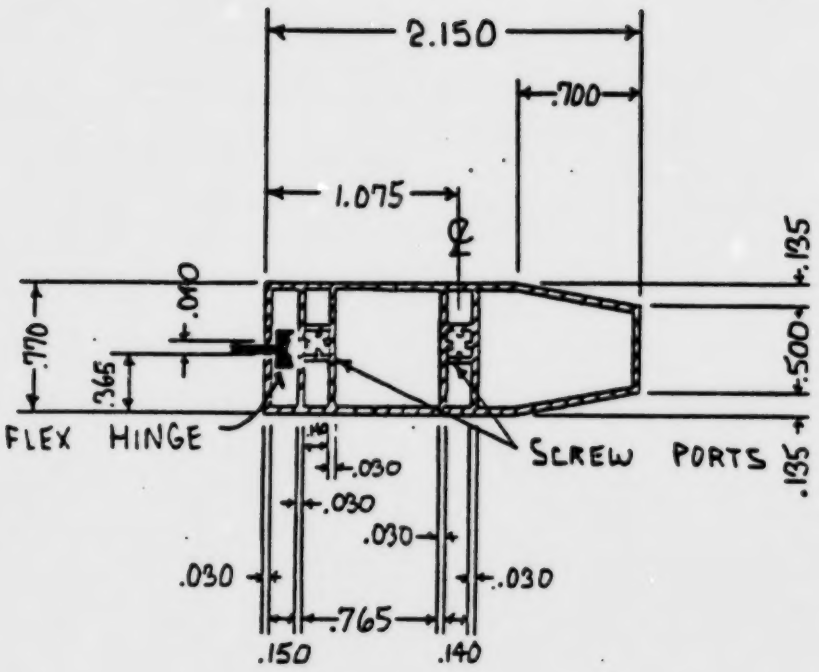
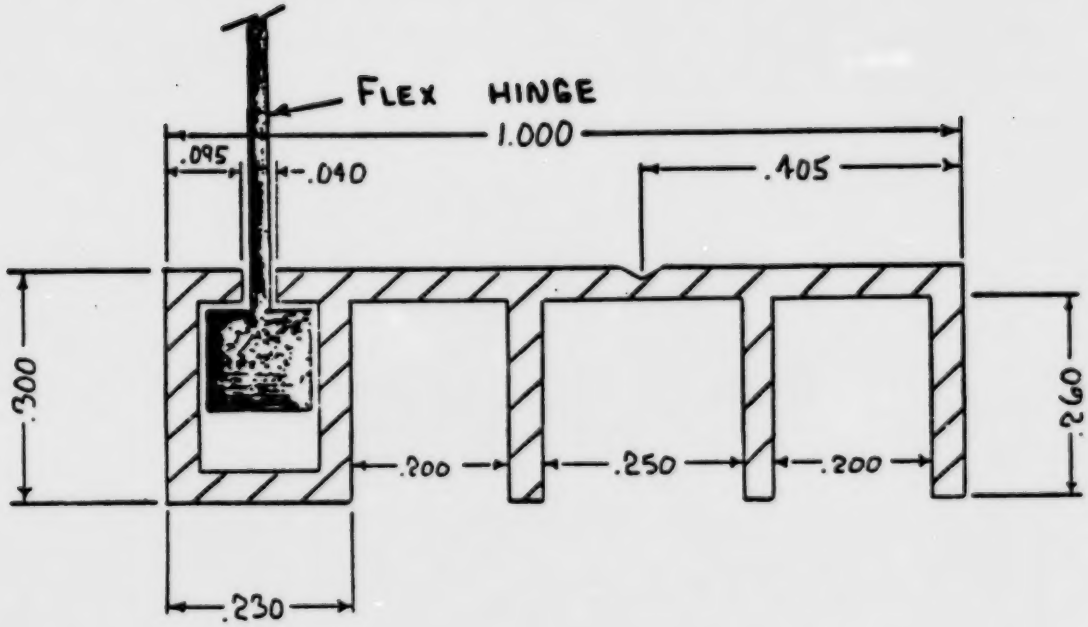


FIGURE 7.7 WALL JAMB



7.2 Profile Design

When designing the dies to produce the profiles which were to be extruded specifically for the production of the PVC folding door, certain technical factors had to be considered. The configuration of the extruder screw, the flow characteristics of the PVC used, die performance, drawdown factors and the relationships among the constituent parts of the entire door when assembled had to be considered when designing the dies.

The different dies varied in their complexity and thus required slightly different manufacturing procedures. The top track and the flex hinge components were the simplest in design because they had no hollow sections. They could therefore be cooled by water immersion and by being passed through a mist produced by atomizing air/water nozzles.

The full and half panel, lead post, and wall jamb profiles were more complex since they incorporated hollow sections in their design. Single thick walls were avoided because during the sizing stage in the extrusion process they tend to become distorted. Instead, double walls were used whenever possible. This resulted in a lighter and more stable profile without sacrificing strength or durability. However, because they were more complicated, these profiles required the more involved vacuum sizing and cooling process. Using this more complicated method has added benefits in the case of these more complex profiles since the vacuum sizer and other calibration equipment used in this process can compensate for any small inadequacies that could exist in the hollow profile dies.

7.3 Assembly

As illustrated in Figure 7.1, the door is principally comprised of a series of PVC panels joined by flex hinges. The flex hinges are composed of thin sections of PVC which run vertically, parallel to the panels. The hinges, possessing the correct flexibility, allow the panels to fold upon each other. The hinge flexibility also allows the panels to maintain their position whether in an open or closed orientation. The hinges remain securely fastened to each panel through friction and through the addition of a small amount of adhesive at each end of the hinge. It is essential that the hinge and the hinge ports on either side of the panels be extruded precisely to the tolerances allowed. If the two are not precise, it will be impossible to assemble them properly. This situation can be avoided through constant tolerance checks during the extrusion process.

A trolley is attached to each panel by screwing a 1 1/2" #6 screw into the screw port on top of the panel. The screw is inserted approximately 1" into the panel. The top track is constructed with enough tolerance to allow the trolley to move freely while allowing enough surface contact to give strength where forces are applied.

A PVC rounded-corner handle is attached to the lead post with 1 1/2" #6 screws complete with washers on the back. The normal installation height would be 40" to center from the floor. This height is adjustable since the handle can be attached to the lead post after the door is installed in an opening in a dwelling. This design element is important from the perspective of handicapped people who may find a handle positioned at a lower level more accessible.

In the closed position the magnet attached to the lead post holds the door firmly and tightly to the metal striker plate secured to the wall. Floating magnets allow the lead post to adapt to openings that are out of square. The door can easily be opened with a firm but gentle pull on the handle.

The wall jamb is secured to the wall vertically by 1 1/2" #6 screws situated at twelve inch intervals. The screw starts in the centre of the wall jamb allows the screws to be easily started. This ensures that the wall jamb is flush with the wall for a finished appearence.

7.4 Economic Feasibility

Rigorous cost analysis based on the preceding design demonstrated that the PVC folding door will be cost-competitive with products presently available to the Alberta market. At both the wholesale condensed (distributor) level and the wholesale (contractor) level, the selling prices were determined to be less that those shown in Table 5.1.

8.0 PROTOTYPE PRODUCTION AND EVALUATION

8.1 The Evaluation Process

The next step in the process involved the production of twenty prototype doors. Sufficient material to manufacture these doors was extruded and die performances were evaluated. Fifteen doors were assembled and evaluated in terms of fit and precision. Ten of these doors were installed in both normal openings and in openings constructed to emulate various problematic conditions. These included openings where the floor was out of level, where the header was out of level, and where the walls were out of plumb (both on the lead post side and the jamb side). In each case, the door's performance was evaluated.

8.2 Extrusion and Die Evaluation

The dies were produced according to the design specifications discussed in Section 7.1. Each die was then attached to the extruding equipment and molten PVC was pumped through. The objective of this testing procedure was to produce a balanced flow of PVC through the die in order to evaluate and adjust the die. Several test runs and subsequent minor adjustments to the die were made to produce profiles that met the standards for thickness of material and accuracy of shape required.

Table 8.1 indicates the amount of material extruded for the prototype doors.

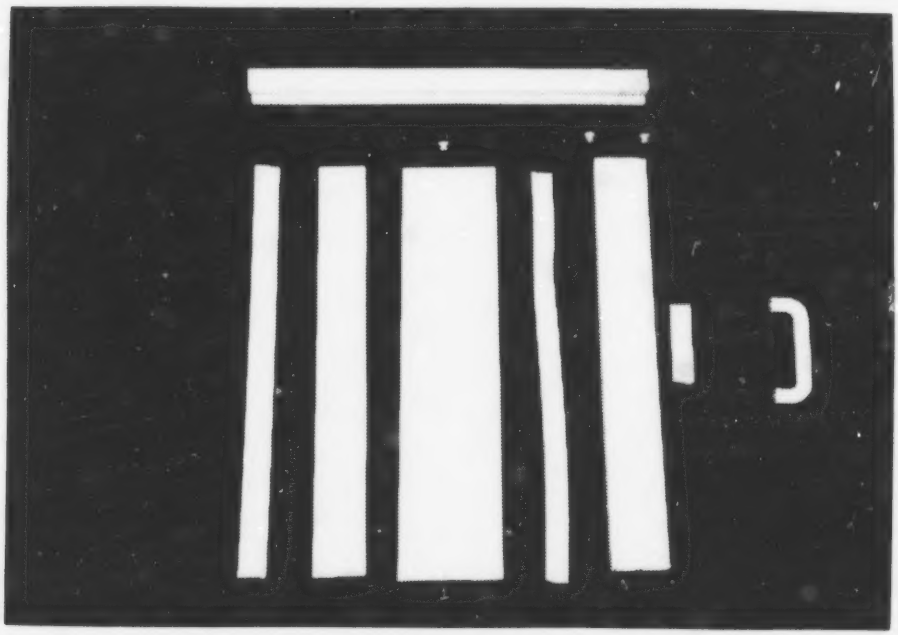
TABLE 8.1 MATERIAL EXTRUDED

Track	80 Feet
Fixed Jamb	120 Feet
Lead Post	1120 Feet
Half Panel	240 Feet
Full Panel	1200 Feet
Flex Hinge	1560 Feet

8.3 Assembly Evaluation

Photo 8.1 is an overview of all the components required in the assembly of the door.

PHOTO 8.1 OVERVIEW OF COMPONENTS



After assembly, it was concluded that all the extruded components met the standards and tolerances required. All the components fit together accurately. Photos 8.2 and 8.3 illustrate that the full panel and the half panel have been extruded precisely to the tolerances allowed. Each possesses the correct configuration to be attached to the flex hinge.

Photos 8.4 and 8.5 reveal that the wall jamb and the lead post also accept the hinge as required. Photo 8.6 shows that the lead post front edge accepts the magnetic catch which allows the floating magnets to move freely in and out. In general, the assembled prototypes fulfilled all the design requirements.

PHOTO 8.2 FULL PANEL AND HINGE

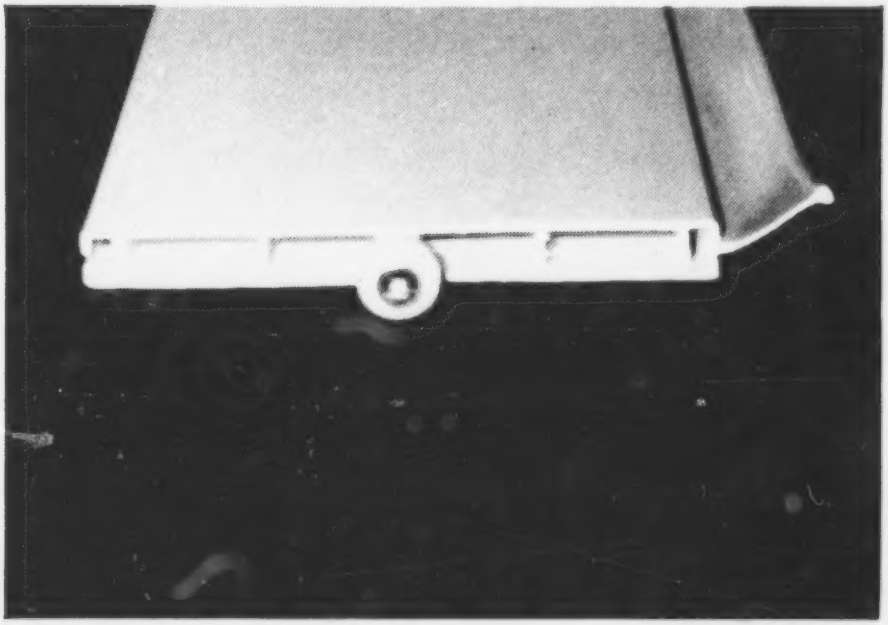


PHOTO 8.3 HALF PANEL AND HINGE

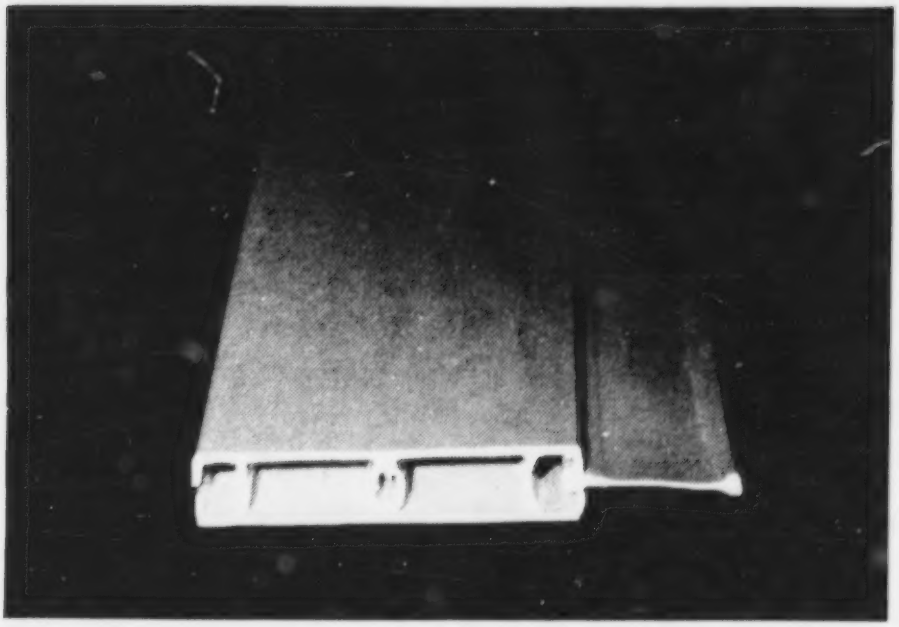


PHOTO 8.4 WALL JAMB AND HINGE

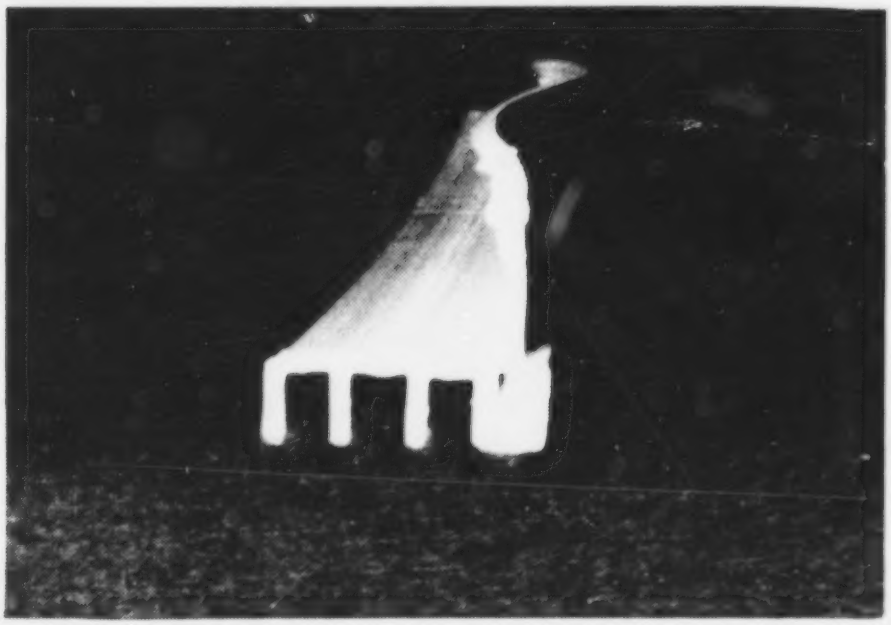


PHOTO 8.5 LEAD POST AND HINGE

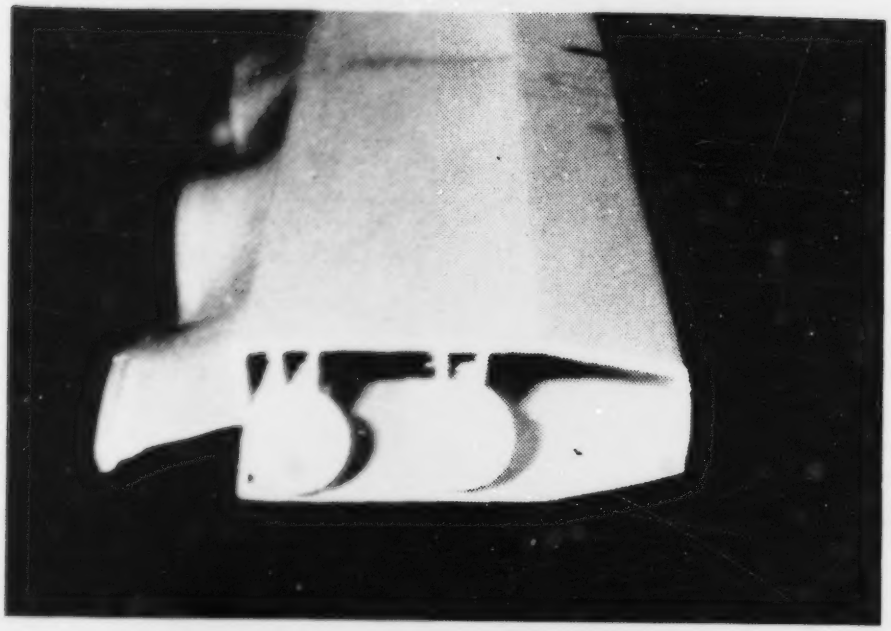
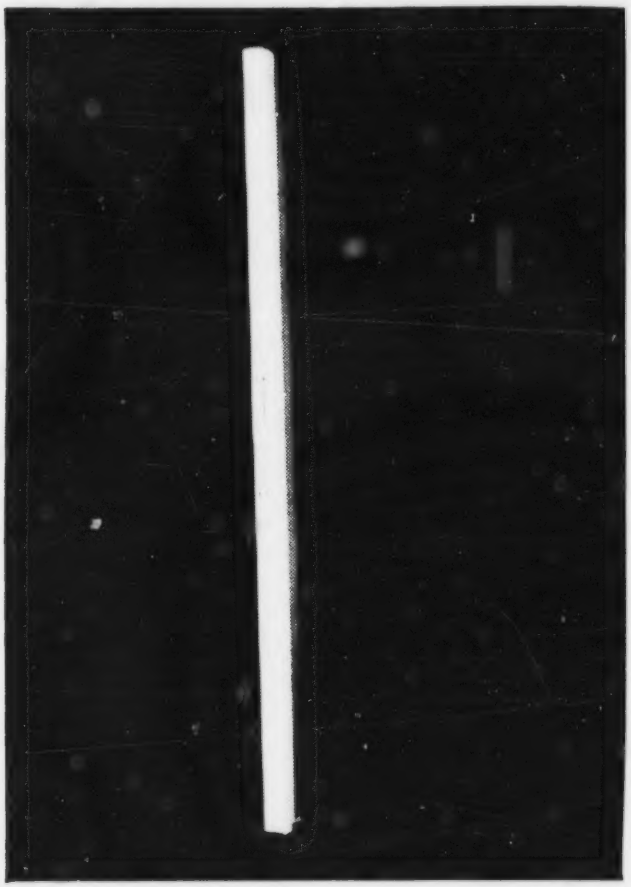


PHOTO 8.6 LEAD POST AND MAGNETS



8.4 Performance Evaluation

A prototype door was installed in a standard opening and a series of tests were performed to evaluate its performance. As illustrated in Photo 8.7, it was found that having two trolleys secured to the lead post ensured that it did not pivot when stationary or moving and that it ran parallel to the centre of the top track when moving in the opening or closing direction. This property of the lead post allowed the half and full panels to fold or unfold properly as the door moved in either direction with the aid of the flexible PVC hinges.

PHOTO 8.7 OPENING AND CLOSING THE FOLDING DOOR

The magnetic catch succeeded in holding the lead post firmly and tightly to the metal striker plate attached to the wall when the door was in the closed position. The handle and the jamb channel all functioned in accordance with design expectations.

The most important feature of any folding door system is the ability of the trolley system to withstand the stress situations encountered in daily use. Once the trolley system begins to fail, other components will be forced to compensate

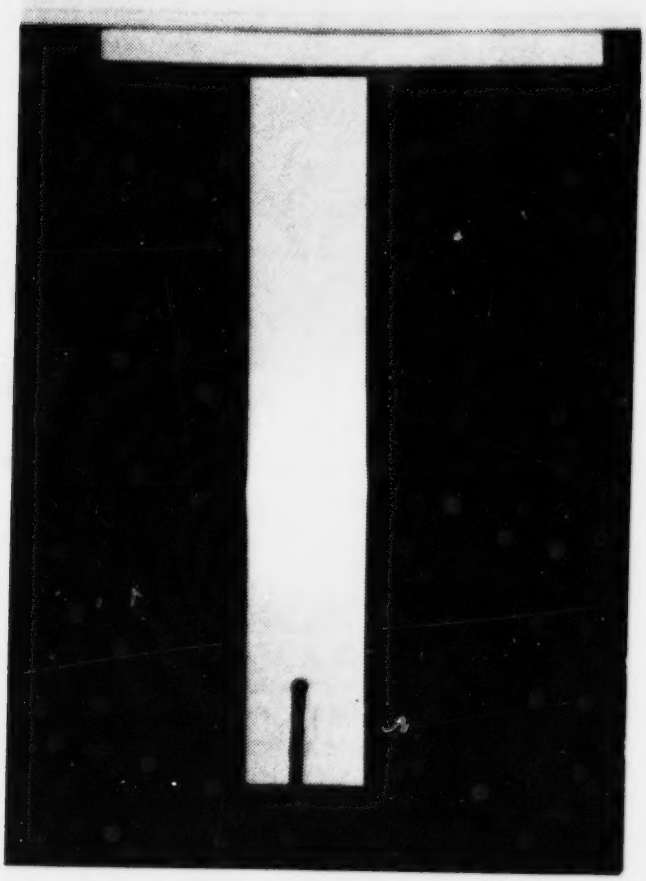
and total failure will eventually follow. Therefore, the performance of the trolley system was rigorously tested.

The three crucial areas to be evaluated were the efficiency of the mechanics of attaching the trolley to the panel, the performance of the trolley itself, and the ability of the track to bear weight.

Photos 8.8 and 8.9 show that the trolley, the screw attached to each panel, and the track are able to hold eighty pounds of weight with no signs of stress. After removal of the weight the trolley system moved freely in the track, unaffected by the force that had been exerted on it. Since each panel weighs approximately three pounds, this test allowed for a safety factor of over 25 times.

PHOTO 8.8 WEIGHT TEST ON TROLLEY

PHOTO 8.9 WEIGHT TEST ON TROLLEY



Photos 8.10 and 8.11 show the door system being moved away from the vertical plane in which it would normally rest. When allowed to return to its normal vertical plane, the trolley system showed no signs of damage and the system moved freely in the track.

PHOTO 8.10 DOOR MOVED FROM NORMAL VERTICAL PLANE

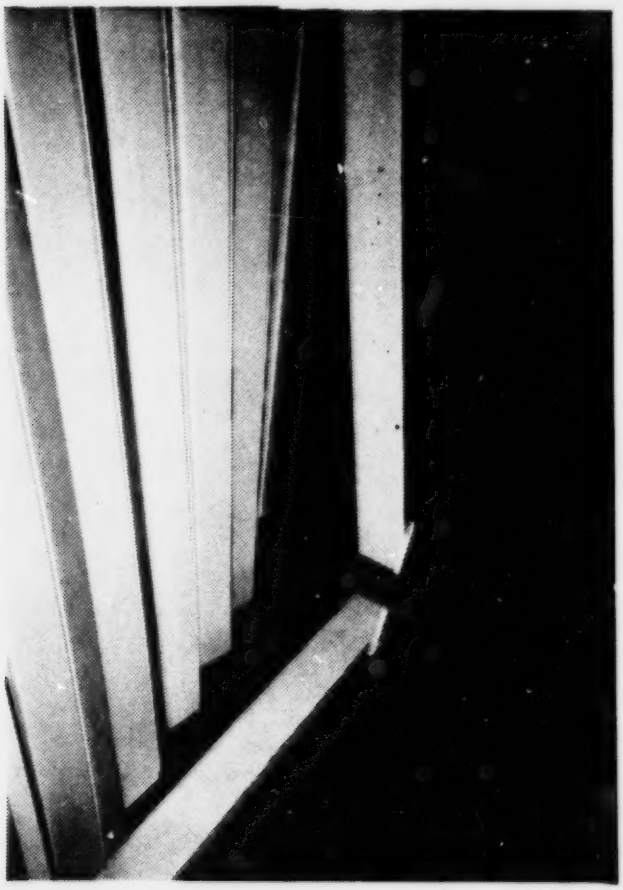
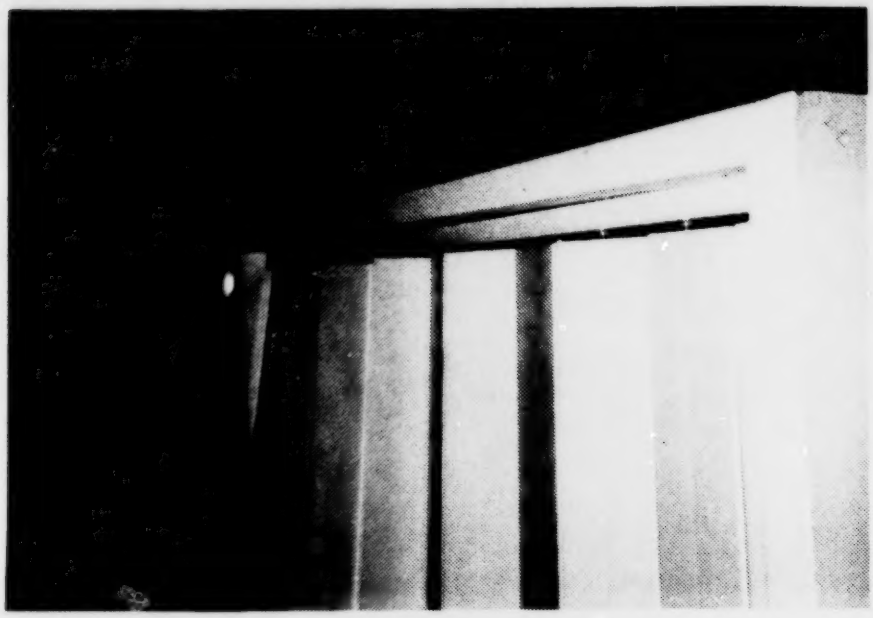


PHOTO 8.11 DOOR MOVED FROM NORMAL VERTICAL PLANE



8.5 Evaluation of Problematic Conditions That May Occur During Installation

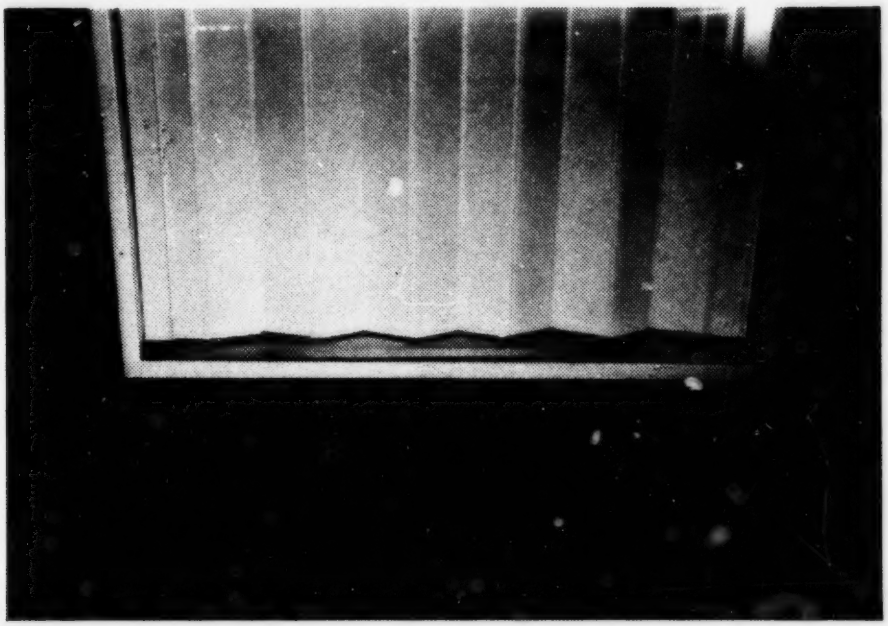
It was concluded that in comparison to other doors available in the marketplace, this PVC folding door was much easier to handle and much faster to install. In all types of openings, whether perfectly square or grossly out-of-square, the door was easily installed and completely adaptable to all openings. The PVC folding door met and exceeded expectations and requirements for fit, ease of installation and adaptability to non-ideal conditions as discussed in the following paragraphs.

8.5.1 Opening With Floor Out of Level

In this circumstance the door was installed in an opening with a one-inch difference in height measurement from one side of the opening to the other. This is caused by a sloping floor, a common occurence in openings. For testing purposes, the slope was exaggerated. Photo 8.12 illustrates the one inch

difference between the right side of the opening and the left side. The folding door worked well in spite of this irregularity.

PHOTO 8.12 OPENING WITH A ONE INCH SLOPE ON FLOOR



8.5.2 Opening with Header Out of Level

Photo 8.13 shows the door system installed in an opening with a one-inch height difference from one side to the other caused by a sloping header. The door opened and closed normally with the slope of the header having no effect on its performance.

Photo 8.14 is a close-up of the top of the door. The trolley, which floats on top of its attachment, adjusts to the opening. The panels are closer to the track on the left side than on the right, but still move freely when opening or closing the door.

PHOTO 8.13 OPENING WITH A ONE INCH SLOPE TO HEADER

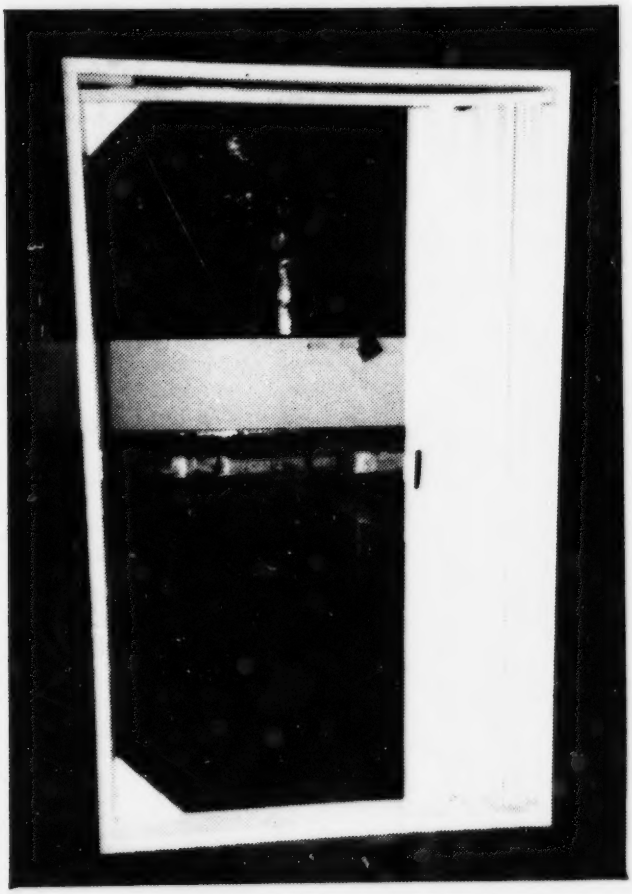


PHOTO 8.14 CLOSE-UP OF DOOR IN AN OPENING WITH A ONE INCH SLOPE

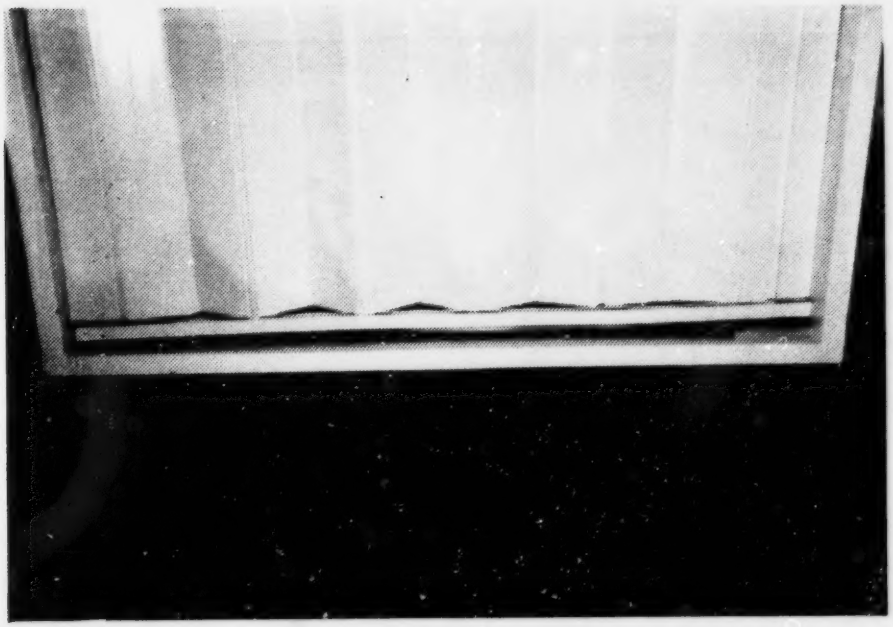


Photo 8.15 shows that the lead post with the floating trolleys and floating magnetic catch adjusted to the out of square condition and aligned itself properly to the wall to give a finished appearence.

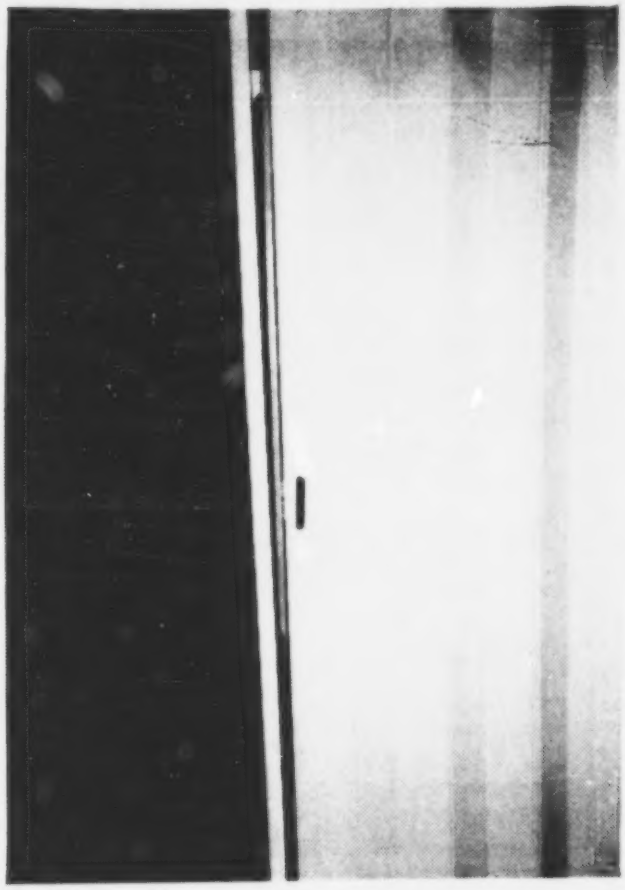
PHOTO 8.15 LEAD POST SHOWN ADJUSTING TO OPENING

8.5.3 Opening with Wall One Inch Out of Plumb, Lead Post Side

The door system was installed in an opening in which the lead post was attached to a wall which was one inch out of plumb from top to bottom. Photo 8.16 shows the folding door in the closed position in this opening. The door moved freely when opening and closing, exhibiting no effect from the out of square condition of the opening. The trolley system and magnetic catch adjusted to the opening and, as Photo 8.17 shows, this allows the lead post to close and adjust to the wall in a normal alignment.

PHOTO 8.16 OPENING WITH WALL ONE INCH OUT OF PLUMB

PHOTO 8.17 LEAD POST ADJUSTING TO THE OUT OF PLUMB WALL



8.5.4 Opening with Wall One Inch Out of Plumb, Jamb Side

The door system was installed in an opening where the wall on the jamb side was one inch out of plumb from bottom to top (see Photo 8.18). The door moved freely with no adverse effect on its performance. Since the wall jamb was securely attached to the wall (see Photo 8.19), there was a tendency for the panels next to that wall to be raised closer to the track. However, Photo 8.20 shows that this does not affect its performance when the door is open to the wall jamb.

PHOTO 8.18 OPENING WITH WALL ONE INCH OUT OF PLUMB

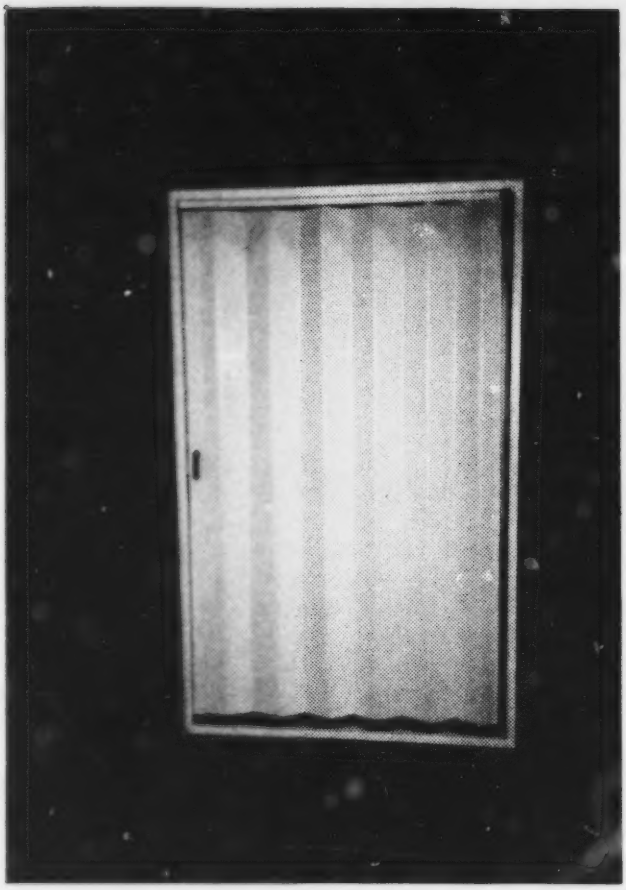


PHOTO 8.19 TOP TRACK AND PANELS

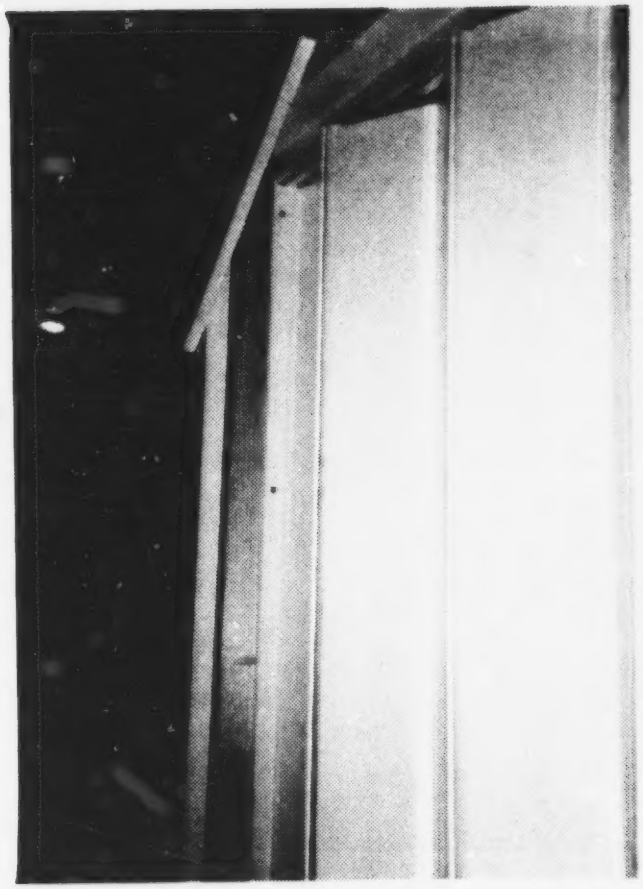
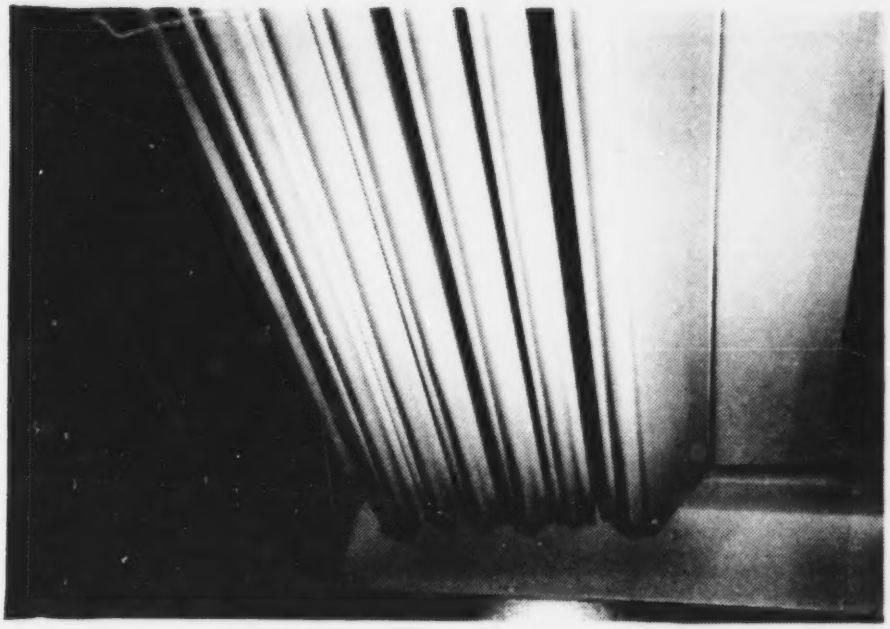


PHOTO 8.20 OPEN DOOR



9.0 CERTIFICATION TESTING AND RESULTS

As was noted in Section 4, the requirement for acceptance of the PVC door consists of a flame-spread rating of 150 or less when tested in accordance with CAN4-S102.2-"Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials and Assemblies". The test quantifies the distance over which a flame travels on the material in a given time period.

Testing was carried out by Warnock Hersey Laboratories in October and November of 1989. To achieve certification, the product under test must demonstrate conformance in each of at least three repetitions of the test procedure.

The PVC door tested well within the 150 flame-spread limit for each of the three test runs. The results are presented in Appendix A. Additionally, the door was tested in accordance with ASTM E84-87, the American equivalent of CAN-S102.2. The ASTM test results are also included in Appendix A.

10.0 CONCLUSIONS

This project has developed a market-ready product. The potential for success of the PVC folding door can be gauged from the following attributes:

-The door has passed the flame-spread testing necessary for recognition within the scope of the Alberta and National Building Codes.

-Rigorous operational testing has demonstrated the PVC door's durability, reliability, and adaptability.

-On the basis of cost estimates PVC folding door can be produced and sold at a lesser price than that offered by the major (provincially) imported competitors.

-The raw materials necessary to meet market requirements currently exist in abundance in Alberta.

-Manufacturing expertise is presently available in Alberta.

Commercialization efforts will encounter some obstacles that must be overcome. Considerable capital expense will be incurred through initial manufacturing-related costs, establishment of the necessary sales and distribution networks, and production and distribution of advertising designed to reach the target market. Additionally, there will be a certain "take-up" time during which the product will have to prove itself in the commercial arena by demonstrating its attributes against competing, established products. This would involve initially slow production rates by a facility geared towards large scale production for the purpose of achieving economies of scale.

BIBLIOGRAPHY

The following references were used throughout this report:

1. Alberta Labour General Safety Services Division, Building Standards Branch, Alberta Building Code, 1985.

2. Canada Mortgage and Housing Corporation, Rental Market Survey, 1988.

3. Canada Mortgage and Housing Corporation, Edmonton Branch Housing Reports, 1988.

4. Consumer and Corporate Affairs Canada, Patents: Questions and Answers.

5. Modern Plastics Encyclopedia, McGraw-Hill, New Jersy, 1988.

6. Government of Canada, B.O.S.S.-Business Opportunity Sourcing System, Canadian Manufacturing Index.

7. Alberta Research Council, World Patents Index, 1963-80 and 1981.

APPENDIX A

FLAME-SPREAD TESTING REPORT

Warnock Hersey

WARNOCK HERSEY PROFESSIONAL SERVICES LTD
211 SCHOOLHOUSE ST. COQUITLAM, BRITISH COLUMBIA
CANADA V3K 4X9 TELEPHONE (604) 520-3321
TELEX: ENVOY WPM 8076 TELECOPIER (604) 524-9186

REPORT OF A FLAME SPREAD TEST PROGRAM

CONDUCTED ON

PVC DOOR PANELS

CLIENT

W.R.S. HOLDING LTD.
11411 - 74TH AVE.
EDMONTON, ALBERTA
P6G 0E7

REPORT PREPARED BY

WARNOCK HERSEY PROFESSIONAL SERVICES LTD.
FIRE LABORATORIES DIVISION
211 SCHOOLHOUSE STREET
COQUITLAM, B.C.
V3K 4X9

REPORT NUMBER: 5793
JOB NUMBER: 50493-C7-579300
DATE TESTED: AUGUST, OCTOBER, & NOVEMBER, 1989
DATE REPORTED: DECEMBER 1, 1989
TEST STANDARDS: CAN4 S102.2M88
ATSM E84-87

VANCOUVER REGINA WINNIPEG SAULT STE MARIE HAMILTON TORONTO MONTREAL HALIFAX ANTIOCH LONG BEACH MADISON BUFFALO BALTIMORE

PREFACE

This report describes the tests, standards and details for the samples selected and submitted by the client. This product is not eligible for certification as no pretest inspection was conducted.

The report does not automatically imply product certification. Products must bear WHI labels in order to demonstrate Warnock Hersey certification.

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FLAME SPREAD CLASSIFICATION	3
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INTRODUCTION

In August, October and November, 1989 the Fire Laboratories Division of Warnock Hersey conducted a test program to determine the surface burning characteristics of submitted accordion door panels.

Testing was conducted in accordance with CAN4 S102.2 M88 "Standard Test Method for Burning Characteristics of Flooring, Floor Coverings and Miscellaneous Materials and Assemblies" and ASTM E84-87 "Standard Test Method for Surface Burning Characteristics of Building Materials".

Upon receipt of the samples at the Warnock Hersey laboratory they were placed in the conditioning room where they remained in an atmosphere of 23 ± 3°C (73.4 ± 5°F) and 50 ± 5% relative humidity until they reach a constant weight.

Four trial runs were conducted on the samples selected and submitted by the client. Three runs in accordance with S102.2 and one run in accordance with E84.

MATERIAL SPECIFICATIONS

The material tested was selected and submitted by the client.

It is described as an accordion style door. The material tested was white PVC material with vinyl flex joints.

Panel: 6 mm x 100 mm (1/4" x 4")

TEST PROCEDURE

The results of the test are expressed by three indexes. Each index expresses the characteristics of the sample under test relative to that of select grade red oak flooring and asbestos-cement board.

(A) FLAME SPREAD CLASSIFICATION:

This index relates to the rate of progression of a flame along a sample in the 25 foot tunnel.

A natural gas flame is applied to the front of the sample at the start of the test and drawn along the sample by a draft kept constant for the duration of the test.

An observer notes the progression of the flame front relative to time.

The flame spread classification for red oak flooring is 100, and 0 for asbestos-cement board.

CALCULATIONS: CAN4 S102.2

According to the test standard, the flame spread classification is equal to 5363 when A_1 is the total area beneath the flame spread curve, if ($195-A_1$) this area exceeds 97.5 minute-feet.

If the area beneath the curve is less than or equal to 97.5 minute-feet the classification becomes $.564 \times A_1$.

CALCULATIONS: ASTM E84

According to the test standard, the flame spread classification is equal to 4900 when A_2 is the total area beneath the flame spread curve, if ($195-A_2$) this area exceed 9.75 minute-feet.

If this area beneath the curve is less than or equal to 97.5 minute-feet the classification becomes $.515 \times A_2$.

TEST PROCEDURE Cont'd:

(B) SMOKE DEVELOPED:

A photocell is used to measure the amount of light which is blocked off by the smoke passing down the tunnel duct.

When the smoke from a burning sample blocks the light beam, the output from the photocell decreases. This decrease with time is recorded and compared to the results obtained for red oak which is 100.

CALCULATIONS:

$$\frac{10{,}000 - (\text{smoke integrator reading}) \times 100}{630}$$

= smoke developed

(C) FUEL CONTRIBUTED:

This is a measure of how much heat energy is given off by the burning of the sample in addition to that which is supplied by the natural gas burners.

The air temperature at the vent end of the tunnel is monitored throughout the test and the results are plotted versus time and compared to the results for red oak.

CALCULATIONS:

$$\frac{1.5 \times (\text{temperature integrator reading})1 - 4968 \times 100}{4195.5}$$

= fuel contributed

TEST RESULTS

FLAME SPREAD

The resultant flame spread classifications, is as follows: (rounded to nearest 5)

FLAME SPREAD CLASSIFICATION

TRIAL	AREA UNDER CURVE	FLAME SPREAD CLASSIFICATION
1 E84	91	50
2 S102.2	131	85
3 S102.2	112	65
4 S102.2	96	55
Average	113	70

SMOKE DEVELOPED

The areas beneath the smoke developed curve and its related classification, is as follows: (rounded to nearest 5)

TRIAL	AREA UNDER CURVE	SMOKE DEVELOPED
1 E84	5600	890
2 S102.2	5866	930
3 S102.2	4908	780
4 S102.2	6268	995
Average	5681	900

TEST RESULTS: Cont'd:

FUEL CONTRIBUTED:

The resultant areas under the time/temperature curve and its related classification, is as follows: (rounded to nearest 5)

TRIAL	AREA UNDER CURVE	FUEL CONTRIBUTED
1 E84	2657	0
2 S102.2	5141	65
3 S102.2	3850	20
4 S102.2	3573	30
Average	4188	30

CONCLUSIONS

The sample of PVC accordion door panels submitted by W.R.S. Holdings Ltd. exhibited the following flame spread characteristics, when tested in accordance with CAN4 S102.2 M88 and ASTM E84-87.

	FLAME SPREAD CLASSIFICATION	SMOKE DEVELOPED	FUEL ** CONTRIBUTED
E84 & S102.2	70	900	30

** This is an apparent value, not a real value

The ASTM E84 test result was within the variation of the S102.2 test results. Therefore it is accepted as having the same Flame Spread Classification

WARNOCK HERSEY PROFESSIONAL SERVICES LIMITED

TESTED BY: _____
Fred Yasuda
Technician
Fire Laboratories Division

REVIEWED BY: _____
Marshall H. James
Supervisor
Fire Laboratories Division

FY/cr

MM/CC/89/12/06

TIME/DISTANCE CURVE

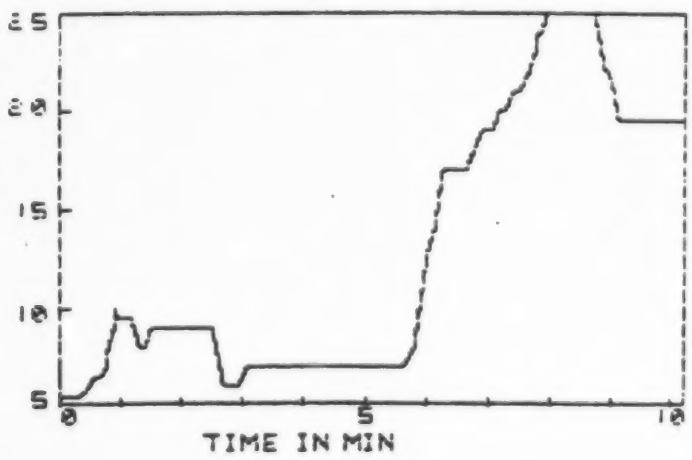
RUN NO. 1

FLAME SPREAD RESULTS FOR :

WRS HOLDINGS LTD.

PRODUCT: PVC FOLDING DOOR
TEST DATE: August 1989
TEST STANDARD: ASTM E84-87
WORK ORDER: 50493-C7-579300
RUN NUMBER: 1

******* FLAME TRAVEL IN FEET vs TIME IN MINUTES *******



********** TEST RESULTS **********

AREA UNDER TIME DISTANCE CURVE 91 FT-MIN
FLAME SPREAD CLASSIFICATION FSC1 51
SMOKE DEVELOPED 888
FUEL CONTRIBUTED 0
MAXIMUM DISTANCE REACHED 25 FT. AT 465 SEC.

TIME/DISTANCE CURVE

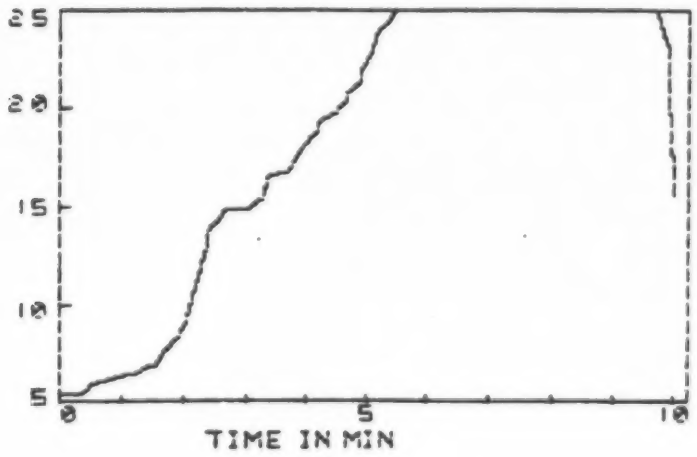
RUN NO. 2

FLAME SPREAD RESULTS FOR :

WRS HOLDINGS LTD.

PRODUCT: PVC FOLDING DOOR
TEST DATE: October 1989
TEST STANDARD: CAN4 S102.2 M88
WORK ORDER: 50493-C7-579300
RUN NUMBER: 2

******* FLAME TRAVEL IN FEET vs TIME IN MINUTES *******



********** TEST RESULTS **********

AREA UNDER TIME DISTANCE CURVE 131 FT-MIN
FLAME SPREAD CLASSIFICATION FSC1 85
SMOKE DEVELOPED 931
FUEL CONTRIBUTED 65
MAXIMUM DISTANCE REACHED 25 FT. AT 465 SEC.

TIME/DISTANCE CURVE

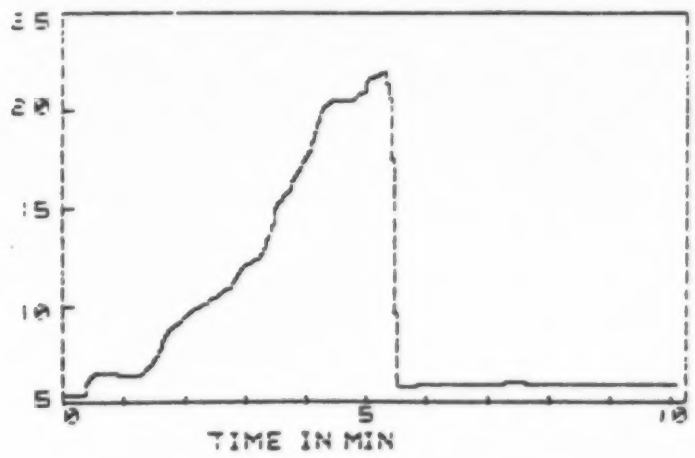
RUN NO. 3

FLAME SPREAD RESULTS FOR :

WRS HOLDINGS LTD.

PRODUCT: P.V.C. FOLDING DOOR
TEST DATE: November 1989
TEST STANDARD: CAN4 S102.2 M88
WORK ORDER: 50493-C7-579300
RUN NUMBER: 3

******* FLAME TRAVEL IN FEET vs TIME IN MINUTES *******



********** TEST RESULTS **********

AREA UNDER TIME DISTANCE CURVE 112 FT-MIN
FLAME SPREAD CLASSIFICATION FSC1 65
SMOKE DEVELOPED 779
FUEL CONTRIBUTED 19
MAXIMUM DISTANCE REACHED 21.9 FT. AT 312 SEC.

TIME/DISTANCE CURVE

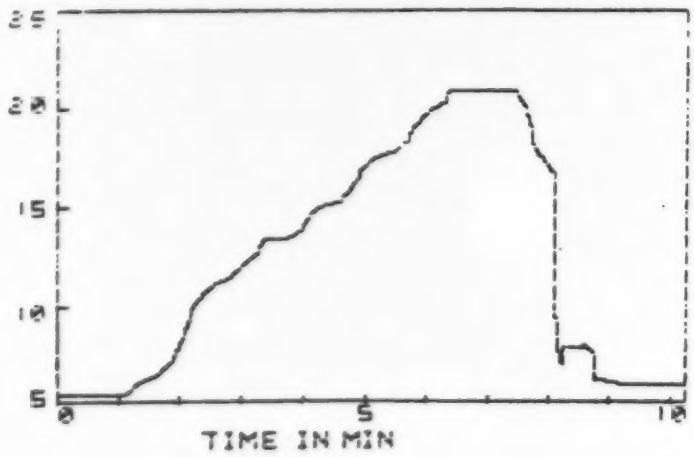
RUN NO. 4

FLAME SPREAD RESULTS FOR :

WRS HOLDINGS LTD.

PRODUCT: PVC FOLDING DOOR
TEST DATE: November 1989
TEST STANDARD: CAN4 S102.2 M88
WORK ORDER: 50493-C7-579300
RUN NUMBER: 4

******* FLAME TRAVEL IN FEET vs TIME IN MINUTES *******

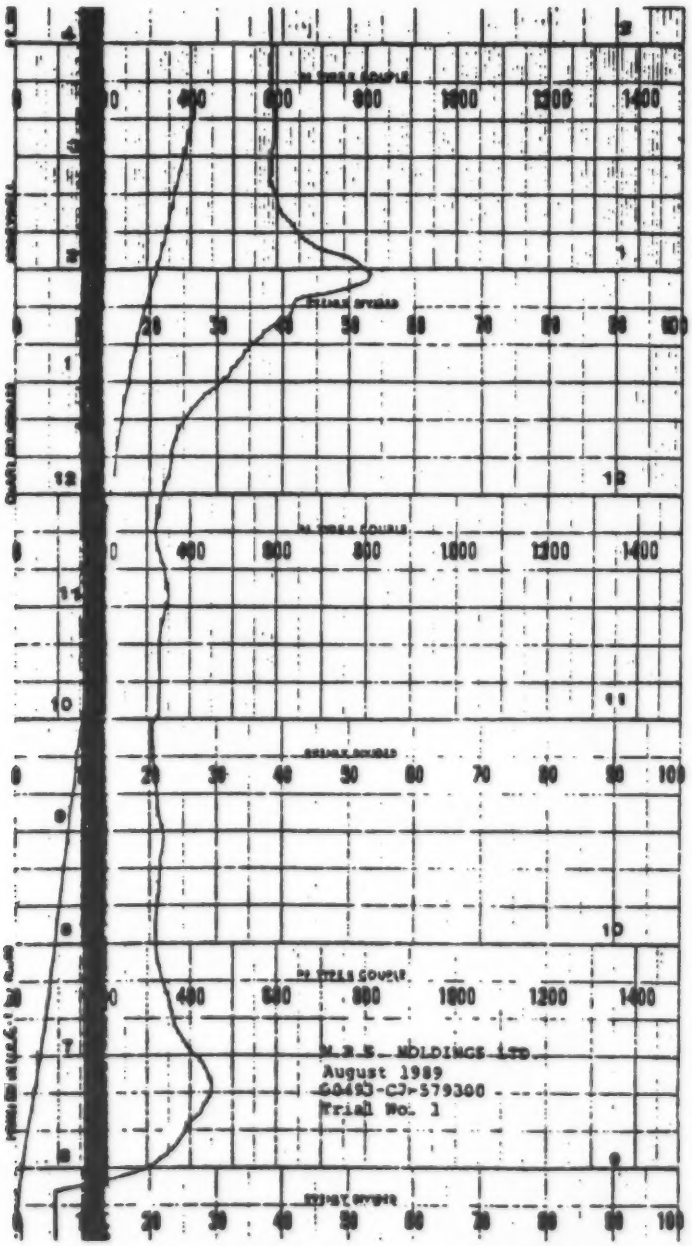


********** TEST RESULTS **********

AREA UNDER TIME DISTANCE CURVE 96 FT-MIN
FLAME SPREAD CLASSIFICATION FSC1 54
SMOKE DEVELOPED 994
FUEL CONTRIBUTED 9
MAXIMUM DISTANCE REACHED 20.8 FT. AT 375 SEC.

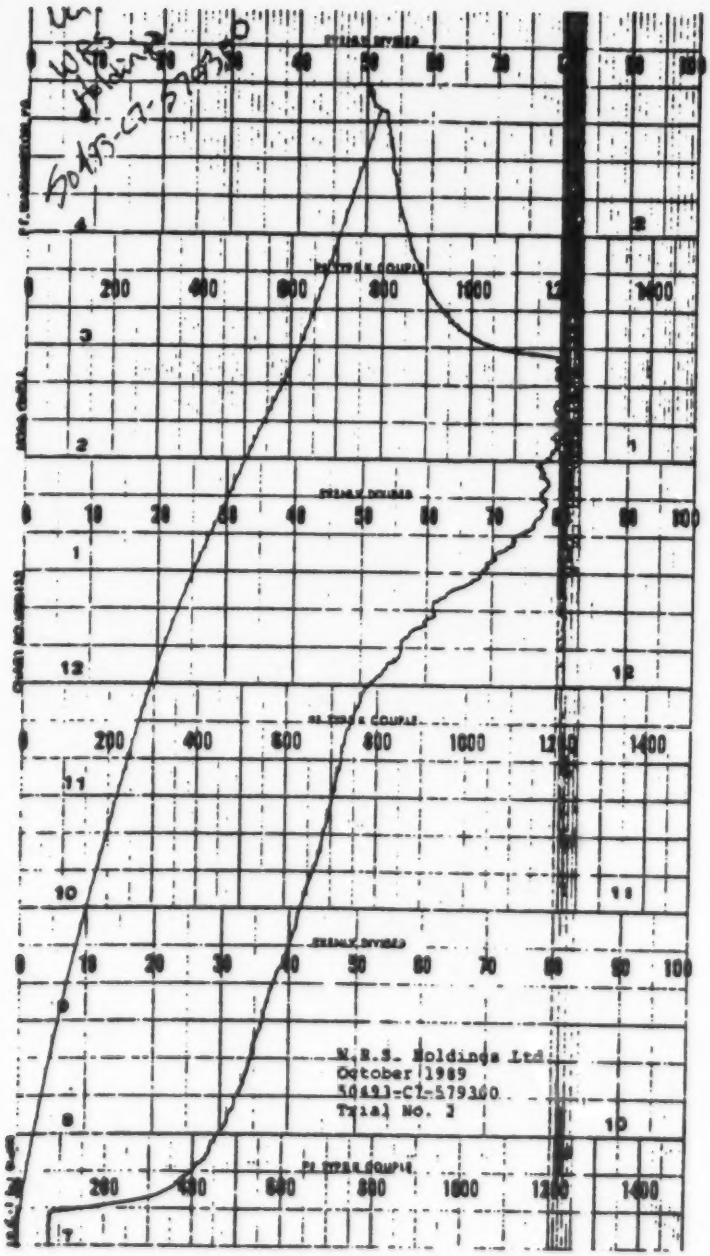
TIME/TEMPERATURE CURVE

TRIAL NO. 1



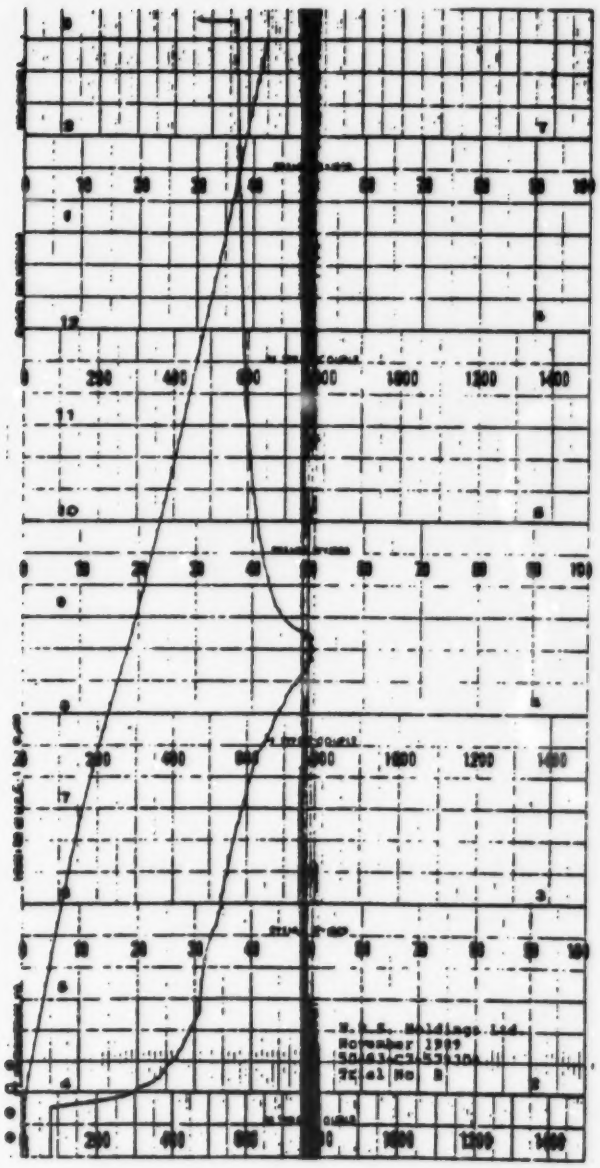
TIME/TEMPERATURE CURVE

TRIAL NO. 2



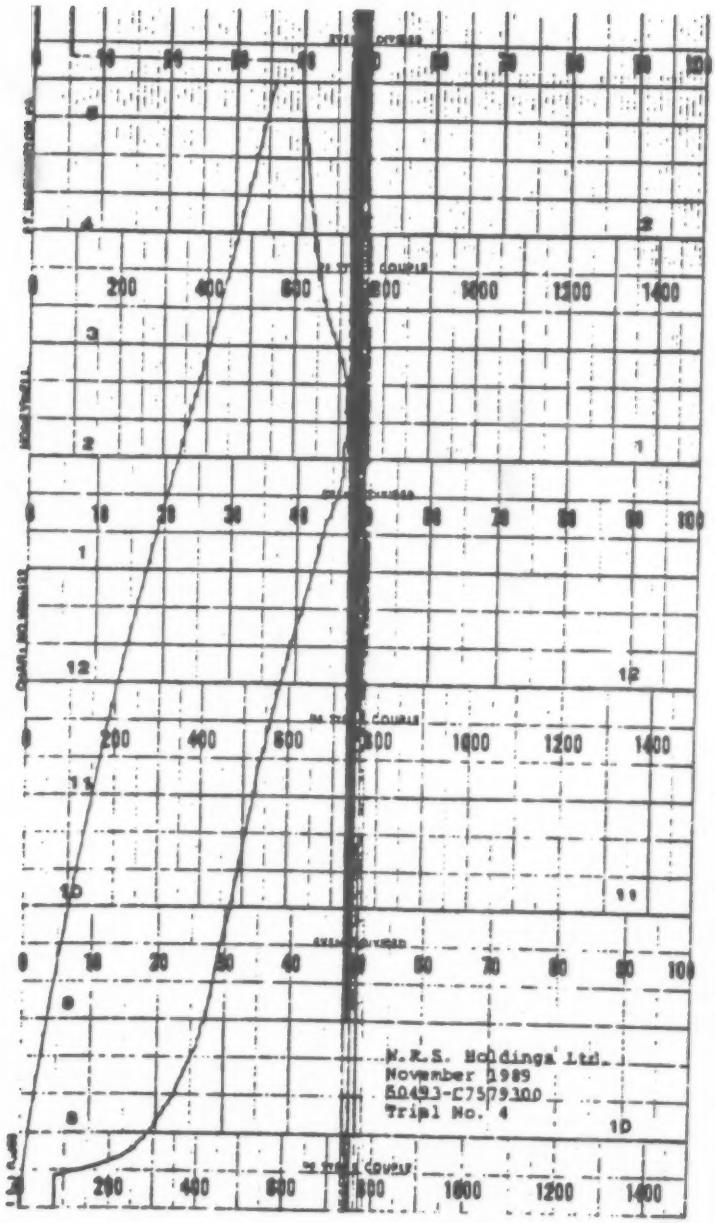
TIME/TEMPERATURE CURVE

TRIAL NO. 3



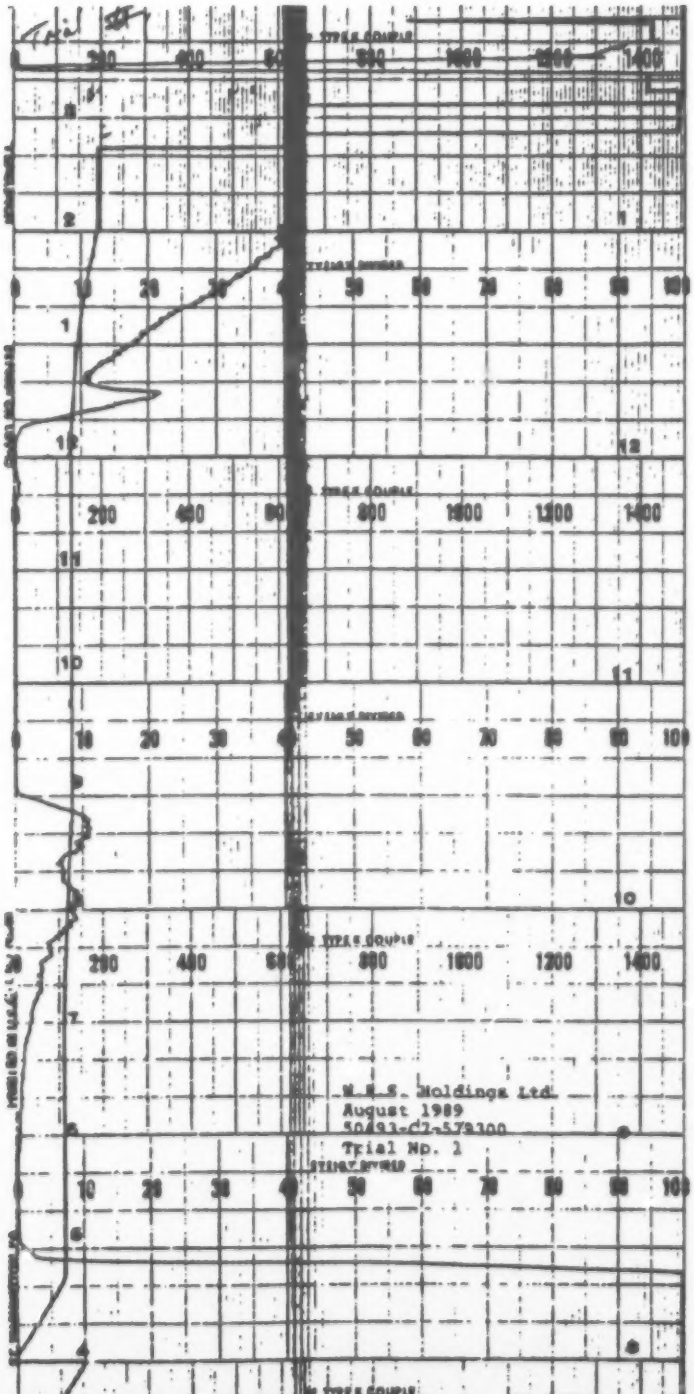
TIME/TEMPERATURE CURVE

TRIAL NO. 4



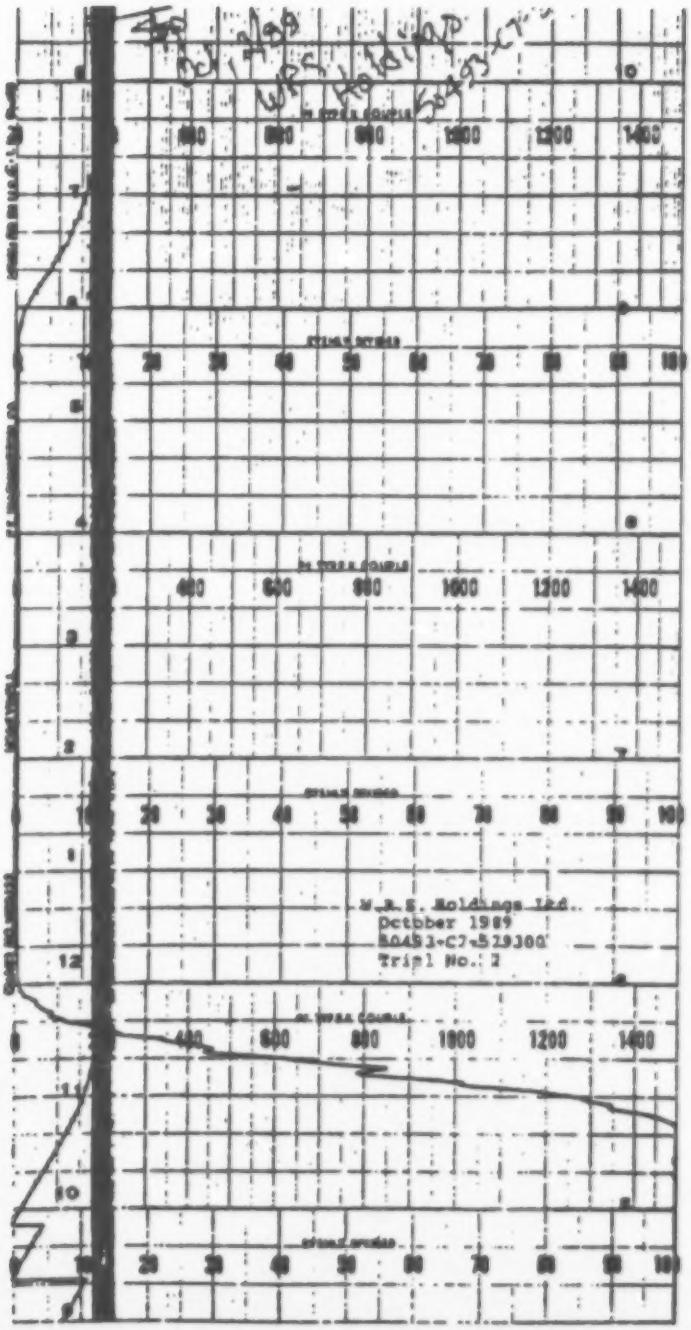
SMOKE DEVELOPED CURVE

TRIAL NO. 1



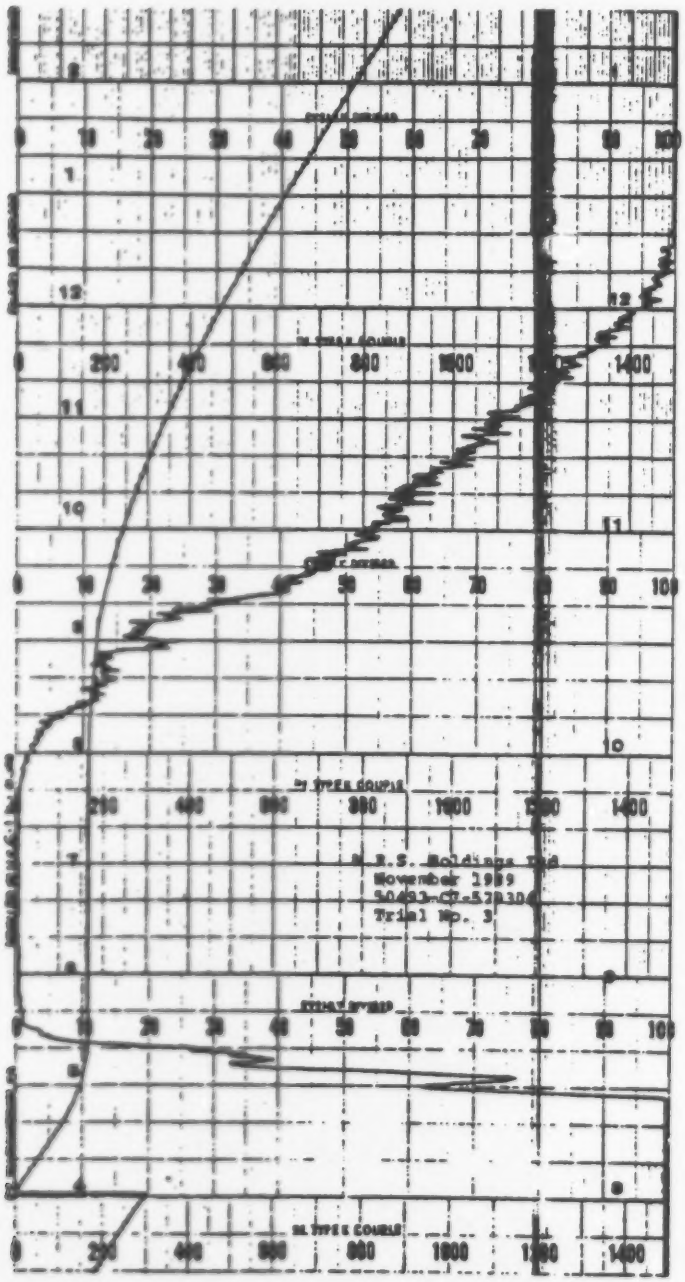
SMOKE DEVELOPED CURVE

TRIAL NO. 2



SMOKE DEVELOPED CURVE

TRIAL NO. 3



SMOKE DEVELOPED CURVE

TRIAL NO. 4